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Comparison of Dry-Cleaning Sponges Used to Remove Soot from Textiles

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COMPARISON OF DRY-CLEANING SPONGES

USED TO REMOVE SOOT FROM TEXTILES

BY

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ABSTRACT

Particulate soil that settles onto textiles can cause mechanical or chemical damage that weakens the object and negatively affects its appearance. Soil removal methods such as vacuuming, wetcleaning, and solvent cleaning may remove unsatisfactory quantities of soil or cannot be used due to the condition or characteristics of a textile. Natural rubber block sponges and polyurethane foam sponges, commonly sold as cosmetic applicators, have been used for surface cleaning by some textile conservators. Published literature that focuses on sponges' efficacy, risks, or benefits is limited; existing research is limited to paintings conservation research and brief mentions in case studies. This study is a comparison of sponge types and brands to determine the most appropriate product for soil removal from the surface of fabrics.

The lack of published standards for textile conservation methods and research required pretests to determine soiling, vacuuming, and sponging procedures. One pretest demonstrated that sponges are effective for a surprisingly small number of tamps before soil is redeposited onto the surface. The method section also includes detailed descriptions of material selection for the sponges, soil, and substrate. Five sponges were selected based on composition, brand, and physical characteristics.

Trial 1, comparing sponge efficacy, found that the polyurethane Studio 35 Beauty™ cosmetic wedge sponge was the most effective at removing soot. Trial 2, testing the number of clean sponge surfaces, found that two to four sponges tamped ten times each may be used to remove soil after which point additional clean sponge surfaces do not remove significant amounts of soil. Trial 3, observing damage to aged textiles, determined that all tested sponges equally produced little damage. Trial 4, evaluating

residue and debris, found that the use of natural rubber sponges should be discontinued, due to the high quantities of potentially damaging residue left after tamping. The most effective sponge in this study was the Studio 35 Beauty™ cosmetic wedge sponge, a small cell polyurethane sponge with calcium carbonate additives.

ACKNOWLEDGMENTS

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PREFACE

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Comparison of Dry-Cleaning Sponges Used to Remove Soot from Textiles

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1. INTRODUCTION

Textiles are vulnerable to damage from soil deposition as small particulates can get trapped between yarns and cause damage as well as affect the appearance. Particulate soil smaller than 0.2 μm can penetrate yarns and weakly bond with fibers. Solid dirt can cause damage through friction between fibers and soil. Dust settled on top of a textile can contribute to discoloration and alter the aesthetic quality of an object, as soil is reliably detected by the human eye in amounts as low as 3.6% surface coverage (Bellan, Salmon, and Cass 2000, 1951). Oily and greasy soils may oxidize causing discoloration and deterioration. Particulate soil also can attract other soils or atmospheric chemicals that damage textiles, dyes, or finishes. Vacuuming, wetcleaning, and solvent cleaning are the most commonly discussed methods to remove soil from textiles (Rice 1972; Reeves 1977, 182; Timár-Balázsy and Eastop 2002, 157-9).[1] The mechanical removal of particulate soil from textiles using dry sponges is a rarely discussed method of surface cleaning that needs attention because it is currently being used by conservators.

Airborne pollutants, including dust and soot, settle on textiles displayed in open museum exhibits. Museums in cities are vulnerable to smog and soot as the finest of these particles can pass through filters and air-cleaning systems (Moffett 2008, 8). Objects in house museums and exhibitions with limited barriers are more vulnerable to particulate accumulation than those in closed cases (Lloyd, Brimblecombe, and Lithgow 2007, 136; Bellan, Salmon, and Cass 2000, 1946). Soot also may be deposited on textiles hung or worn in candlelit areas, such as tapestries and liturgical garments and cloths. Normal accumulations of dust, fibers and soil generated and introduced by visitors, are addressed

[1] Recent sources reference these texts without adding to the topic.

by vacuuming during exhibition maintenance, while more severe cases may require special attention (Lloyd, Brimblecombe, and Lithgow 2007).

Disasters, such as wildfires, building fires, and furnace puff-backs, can introduce smoke carrying soot and particulate soils throughout a museum or historic house. Improvements in fire suppression systems reduce the number of objects that are damaged by fire and water; but by the time these systems respond smoke will have quickly spread through a building (Silverman and Irwin 2009, 31). The specific characteristics of smoke and soot are dependent on the source of fuel. Not only are soot particles extremely small, 0.05 to 1.0 μm, but they are slightly acidic and have oily components that make removal difficult (Hackett 1998, 63-4; Druzik and Cass 2000, 22).

Many notable textile conservation texts divide soil removal into the following categories: surface cleaning, wetcleaning, and solvent cleaning methods. Surface cleaning includes the use of suction, blowers, brushes, and sponges. Landi recommend adhesive tape to remove surface soil, but this is not mentioned in newer sources (Landi 1992, 37; Timár-Balázsy and Eastop 2002; Lennard and Ewer 2010). Wetcleaning uses water with additives such as surfactants, bleaches, enzymes, and chelating agents to clean textiles. Commonly known as drycleaning, solvent cleaning is "the removal of soiling by organic solvents" (Timár-Balázsy and Eastop 2002, 175). Both wetcleaning and solvent cleaning can be executed by full immersion in solution or localized spot cleaning. These cleaning methods are used for a broad range of soiling though special considerations must be taken for the removal of soot.

Specialized handling during salvage operations is vital to limiting the damage caused by soot deposition. As an object is handled, small particulates are pushed into the surface between yarns and fibers increasing the difficulty of removal. Handling is therefore minimized whenever possible to reduce soil penetration (Roberts, et al. 1988, 9). Interleaving materials are used to prevent the transfer of soot from a soiled surface to a clean surface. Following careful handling procedures after a disaster will reduce the amount of soil embedded in the fibers by handling and make the subsequent soil removal more successful (Francis 1998, 38-42). Once the salvage operations are complete, cleaning must be executed in a timely manner to prevent staining and long term damage (Hackett 1998, 66; Spafford-Ricci and Graham 2000b, 52).

Vacuuming is an important initial step in cleaning soot covered textiles. In some cases of heavy disposition, vacuuming should be carried out before objects are moved (Spafford-Ricci and Graham 2000b, 53). Surface contact of the vacuum hose is always avoided with vulnerable textiles and is often recommended that a screen be placed directly on the textiles to prevent them from getting sucked up into the hose (Wolf 2002, 36-7; Lennard and Ewer 2010, 218; Victoria and Albert Museum 2016; Canadian Conservation Institute 2010). The potential for soot to be embedded in the surface of a textile due to handling means that a screen cannot be used; vacuuming must be completed without any surface contact. Without a screen the distance between the textile and the hose must be increased or the suction level decreased. Though sufficient in cases where only a very light accumulation of dust or soot has occurred, suction is often ineffective at removing the smallest particulates. Vacuuming is followed by surface cleaning, wetcleaning, or solvent cleaning to remove a satisfactory amount of soil. After vacuuming, other surface cleaning methods are used to remove additional particulate soil. Mechanical removal of particulates is done using brushes or dry sponges, sometimes removing enough soil to make wet cleaning and drying cleaning unnecessary (Hackett 1998, 64; Spafford-Ricci and Graham 2000b, 47-53). Dry sponges offer a method to remove surface soil that has accumulated over time as well as soil deposited after a soot disaster.

Wetcleaning can be used to remove soot after vacuuming and surface cleaning methods have been completed only if the object is sufficiently resilient (Roberts, et al. 1988, Hackett 1998, Spafford-Ricci and Graham 2000b). As an invasive and irreversible process, wetcleaning carries risks that may outweigh the potential for damage from leaving soil in place. Many textile characteristics can be irreparably damaged by wetcleaning. Fibers swelling in water may cause dimensional changes to fabric structure; knit fabrics and bias cut garments are prone to distortion. Pigment binders and water-soluble dyes may break up or dissolve during wetcleaning, leading to dyes running and color loss. Embellishments are also vulnerable to water: gelatin sequins may dissolve, metallic threads can corrode or be broken by the swelling of the fiber core, and fur and feather trims might be deformed (Timár-Balázsy and Eastop 2002, 194; Canadian Conservation Institute 2009). The hydrophobic nature of soot makes wetcleaning difficult, even with the presence of surfactants.

Solvent cleaning may be used more effectively than wetcleaning and is usually contracted out to commercial drycleaners. Drycleaning solvents are effective against oily soils, such as soot. While often successful at removing soot, the agitation required for machine solvent cleaning can damage fragile textiles during the cleaning process. Some conservators may have access to facilities to use solvent clean textiles in open trays, but this could be impractical in a disaster recovery situation. Many of the textile characteristics that are vulnerable to water are not affected by solvents, though there are dyes and trims that may be dissolved by solvents (Hackett 1998; Armstrong, et al. 1981; Timár-Balázsy and Eastop 2002, 175-6).

Size, construction and design may require treatment of objects in situ that is not compatible with wetcleaning or solvent cleaning. Upholstered furniture may have large surface areas on which airborne pollutants may easily collect, as their wooden frames prohibit full immersion in water. Some rugs are large enough to make wetcleaning and solvent cleaning impractical. Poultices have been used in case studies, but they lack the support of controlled testing (Roberts, et al. 1988, 9-10). Although wetcleaning and solvent cleaning can be effective methods to clean sooty textiles, surface cleaning is part of the process or is the final process when the risks outweigh the benefits.

The mechanical removal of soil from paper and paintings is more commonly cited in the literature than for textiles due to those objects' sensitivity to aqueous solutions. Recently published research about dry cleaning methods on painted surfaces compared products such as "sponges, erasers, malleable materials, and microfiber cloths" (Daudin-Schotte, et al. 2012, 211).[2] Sponges included natural rubber sponges (also called dry cleaning sponges, soot sponges, chem sponges, and vulcanized rubber sponges) and polyurethane sponges, most commonly sold as cosmetic applicators.

As the characteristics of paper, paintings, and objects are very different than those of textiles, caution should be used before applying painting and object conservation techniques to textiles. Paper, object, and painting conservators use mechanical methods to remove soil that work well on flat and nonporous surfaces; these techniques are

[2] "…yellow microfiber cloth, white akapad, and polyurethane-based makeup sponges were shown to be the most effective and safe materials" on painted surfaces. (Daudin-Schotte, et al. 2012, 209)

inappropriate and possibly ineffectual for fibrous and textured surfaces of textiles. Some products, such as kneaded erasers or rubber erasers leave crumbs that are easily removed from a flat surface such as paper, but can get caught in between yarns or fibers (Pearlstein, et al. 1982, 11; Estabrook 1989, 79-80). Other products are simply too abrasive due to the method of application, i.e. rubbing the eraser across the surface. Research into residue left by natural rubber sponges found that Absorene brand sponges left surface deposits on “rougher, more absorbent surfaces” such as unprimed cotton duck used for painting canvas (Digney-Peer and Arslanoglu 2013, 231). Researchers who address “textiles” only look at painting canvas, which is sturdier than many garments and decorative textiles.

Textile conservators have also adopted small cell polyurethane sponges, usually sold as cosmetic sponges, as an effective and inexpensive surface cleaning material. These sponges are considered to be less abrasive and more effective than the natural rubber sponges previously cited in case studies (Moffatt 1992; Hackett 1998). While published material about the use and testing of sponges is limited, conservators regularly mentioned them in conservation blogs as a treatment (Anthropology Conservation Laboratory 2004; Winterthur Museum, Garden & Library 2009; Gleeson 2015). Research on residue left by surface cleaning objects with natural rubber sponges has produced evidence that small pieces of sponge or sponge filler can be left behind, which suggests a potential for residue left behind from the use of polyurethane sponges as well. Polyurethane is not recommended for use in storage or display mounts as it may cause “the deterioration of fibers and the discoloration of dyes and pigments” (Timár-Balázsy and Eastop 2002, 342). Any residue left on the surface of the textile represents potential for chemical or mechanical damage. Comparing the effectiveness and risks of using different sponge types for cleaning textiles would help conservators make informed \decisions. Soot is a problematic soil to remove from textiles, the small particle size and oily component make it difficult to remove.

Published research concerning the removal of soot from textiles is limited to case studies. Most of these studies occurred after a disaster when time and resources were strained. During the recovery of a furnace puff-back in 1980 at the Museums of Stony Brook, staff used vacuuming, wetcleaning, and solvent cleaning to remove soot, with notes that some textiles may be too delicate to withstand the agitation required in wetcleaning or solvent cleaning to suitably reduce the amount of soot (Armstrong, et al. 1981). A fire at the Royal Saskatchewan Museum was well documented and published with great attention to detail. Spafford-Ricci and Graham outlined cleaning procedures that "proceeded from vacuuming to dry-surface-cleaning methods and then as needed to wet-cleaning agents" (Spafford-Ricci and Graham 2000a, 26). They found soot sponges to be very successful at removing soot as a partial or full treatment for bird feathers, painted surfaces, finished wood, and semi-tanned hide. Soot-covered textiles were treated by vacuuming and wetcleaning or solvent cleaning the objects (Spafford-Ricci and Graham 2000b, 46-9).

A house fire at the Higley family home in Delaware produced very oily soot characteristic of building fires that did not respond well to vacuum treatments. Conservators used natural rubber sponges to successfully reduce the soot, often followed by wetcleaning or solvent cleaning treatments, citing the use of sponges by the conservators at the Royal Saskatchewan Museum though that institution did not use the sponges on textiles. Concerns about reside left behind after the use of natural rubber sponges prompted a study that utilized the Oddy test.[3] Reside left by the sponges tarnished the metal coupons; sponge fragments may be successfully removed by re-vacuuming after treatment. No particulate sponge residue was found using a scanning electron microscope. Hacket recommends that textiles should vacuumed before and after treatment, and notes that the Oddy test is subjective and not sensitive to small particulates (1998, 67).

Not all case studies focus on disasters; surface cleaning with sponges is used to clean both the painted and unpainted sections of flags and banners. Rubber sponges were used to clean the silk ground of a miner's union banner (Lennard and Ewer 2010, 128). The conservators of the Star-Spangled Banner sought to remove harmful particulate soil along with fatty acids and oils that had accumulated over time while on display. Dry sponge cleaning reduced soil and improved the overall appearance of the flag without damaging it. The conservators used polyurethane wedge sponges during the cleaning phase of conservation (Smithsonian National Museum of American History 2014; Ordoñez 2016).[4]

The ethical discussion of whether or not to clean an object has been addressed elsewhere (Appelbaum 1987; Eastop and Brooks 2011). This study identifies the most suitable sponges to remove soot from textiles once the decision to clean an object has been made. A variety of sponges sold by conservation houses were tested alongside

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[3] The Oddy test was developed to test the safety of materials for storage and exhibition of museum collections. A sample of the material is placed in a container with metal coupons and subjected to high humidity and heat. Corrosion on the coupons reveals whether or not a material will off-gas and what types of corrosive agents may be present. (Oddy 1973)

[4] Dr. Ordoñez was a member of the Technical Advisory Group of the Star-Spangled Banner Preservation Project.

commercially available polyurethane makeup and natural rubber sponges. The methodology section includes detailed descriptions of the pretests and research required to establish a method for the main trials of the study. Discussion of materials will address factors such as sponge characteristics and availability to help conservators make an informed decision when selecting sponges. Trials determined the efficacy of removing carbon black from the surface of textiles, amount of fiber ends dislodged from yarns, dislocation of yarns in the fabric structure, and amount of residue produced by the sponge.

2.0 METHOD

This study developed from a summer internship project that used cosmetic sponges to surface clean tapa cloths. Object conservators who considered latex-free polyurethane cosmetic sponges as an acceptable and cost-effective treatment use the sponges to gently remove surface soil. Textile conservators also have adopted this cleaning method, despite little published literature addressing the efficacy or risk of using these sponges. This study determines if polyurethane sponges are an appropriate choice for surface cleaning textiles and how they compare to the natural rubber sponges long used and recommended by conservators (Moffatt 1992; Hackett 1998; Vine 2005; Storch 2011). Research and availability of appropriate products guided the selection of sponges, substrates, and soil. The lack of clearly established treatment procedures and testing methods required multiple pretests to design the core trials. Pretests established methods of soiling, vacuuming, and sponging; these were small scale so further research and development of test methods would be beneficial to conservators. Four trials addressed the primary variables of efficacy, damage, and residue.

2.1 SELECTION AND PREPARATION OF SPONGES

2.1.1 Sponges

A variety of brands and types of sponges were purchased from national chain stores or internet sites. Compared by visual examination and physical characteristics for selection in the study, sponge types include natural vulcanized rubber, latex, and polyurethane foams. Initial characterization of sponges focused on materials and physical characteristics. Sponges were evaluated at 25x with the stereo light microscope, Nikon SMZ800 with a Nikon Digital Sight DS-Fi1 camera. Image-Pro software was used to measure cell density, average cell size, and cell size range. The SEM, JEOL JSM-5900 Low Vacuum, was used to characterize the sponges at high magnification. Additives present in the sponges were identified using energy dispersive spectroscopy, EDS, which detects the elemental components that were later associated with known sponge fillers and additives. Firmness was evaluated by comparing and describing each sponge to categorize the sponge types. The differences and similarities between brands and sponge types are described in detail in section 4.1, Sponge Characteristics.

Natural rubber sponges are promoted for removing soot from walls, furniture, draperies, and other objects after a fire. This sponge type is sold by conservation supply houses, recommended for use on tapestries and other textiles. The advertising copy cites no research to indicate that they are better than their commercial counterparts (University Products: The Archival Company 2015; Gaylord Archival 2015). Latex foam sponges, used as cosmetic applicators, are available from high-end cosmetic companies. Polyurethane foam sponges are commercially available as cosmetic applicators and also are offered by conservation supply houses such as University Products and Gaylord

Archival. A polyurethane wedge and a natural rubber sponge intended for use by conservators were chosen to determine if the products were substantially different from their commercial counterparts. As this study is most applicable to disaster recovery, the time to acquire sponges, whether available in stores on online, was included in the evaluation.

Due to concerns about allergic reactions, latex cosmetic sponges are becoming increasingly difficult to find (Alenius, Turjanmaa and Palosuo 2002). One brand was discontinued between starting this research and submitting the proposal for the study. As a result, a latex cosmetic sponge was briefly examined but not considered for use in the trials.

The various brands of polyurethane cosmetic sponges have different pore sizes, roughly characterized as “large-cell” and “small-cell.” All evaluated small-cell cosmetic sponges were composed of a wide range of pore sizes. Measured as the area of open space of the cell, the pores of small-cell sponges range from approximately 65 μm^2 to 69,000 μm^2, with an average pore size of 7,255 μm^2. The pores in large-cell sponges were more regular than those in the small-cell sponges, with an average pore size of 31,700 μm^2. One sponge of each cell size was chosen for the study. No notable difference existed between brands of natural rubber sponge so the most widely available commercial soot sponge, Paint USA®, was chosen. Absorene Dry Cleaning Soot Sponges also are widely available but were not selected as published research already demonstrated that these sponges left residue on “rougher, more absorbent surfaces,” such as unprimed cotton duck used as paint canvas, which could be similar to some upholstery fabrics (Digney-Peer and Arslanoglu 2013, 231).

Five sponges were chosen for the major trials of this study: University Products Dry Cleaning Sponge (natural rubber), University Products Latex-Free Hydrophilic Sponge (polyurethane foam), Paint USA® K-42R Soot & Dirt Remover (natural rubber), Studio 35 Beauty™ Cosmetic Wedges (polyurethane foam), and up & up™ Latex Free Foam Cosmetic Wedges (polyurethane foam). Each of the five chosen sponges displays unique characteristics.

Commercial sponges not selected exhibit redundant features such as cell size and were characterized but not included in the final study. Brands of cosmetic sponges evaluated but not tested include polyurethane CVS® Essence of Beauty™, Rite Aid® Renewal™, and Ulta® Beauty, and latex MAC wedge sponge. Natural rubber sponges evaluated but not tested include Gonzo® Wonder Sponge™, EZ One® Soot and Dirt Remover, and Wishab soft yellow sponge. The scope of this thesis limited how many sponges and variables could be tested; only the sponges that were notably different from the others within the established parameters were included.

2.1.2 Sponge preparation

Polyurethane sponges are sold in blocks of pre-cut wedges and natural rubber sponges are sold in blocks that usually are cut into smaller pieces by conservators to maximize usable surface area. For consistency in comparative trials, all sponges were cut into equal sized cubes as the shape and size of the sponge are controllable variables. Sponges were cut into1.3 cm^3 (0.5 $in.^3$) cubes. The nature of the sponges made it difficult to produce perfect cubes but efforts were made to ensure that at least one side was as square as possible. Systematic rotation of sponge brands for treatments during trials was used to reduce the impact of human variation. Sponge brands were randomly assigned a letter; cubes were stored in separate and labeled sealed plastic bags. Cubes were removed randomly from their labeled bag for testing. After the data were analyzed, brand names were reassociated with the results.

Some sources suggest rinsing sponges before use or reuse, while others assert that rising will reduce sponge efficacy. Daudin-Schotte, et al. recommends rinsing polyurethane sponges as a precaution against sponge additives that might be left behind as residue on the treated surface. Natural rubber sponges were not rinsed in their study (Daudin-Schotte, et al. 2012, 217). Anecdotal evidence from conservators suggests that washing or rinsing rubber sponges will decrease their efficacy, either before use or after treatment for reuse (Mowery 1991; Hackett 1998, 64; Herford 2004). Insufficient and conflicting literature requires further research of the efficacy and consequences of rinsing sponges. Such research is outside the scope of this study, so sponges were examined and tested without rinsing.

2.2 SELECTION AND PREPARATION OF SUBSTRATE

2.2.1 Substrate

While textiles made of manufactured fibers are extremely common today, clothing and textiles in historic collections predominately are made of natural fibers such as cotton, flax, wool, and silk (Canadian Conservation Institute 2015, 1). The distinct characteristics of each fiber affect soil retention and removal; the scope of the study was limited to cotton fabric.

The natural aging process of fabrics produces inconsistencies that present as uncontrolled variables. Two samples from the same length of fabric may not behave the same in laboratory tests. Commercially available cotton fabrics were obtained for pretests and efficacy trials, as these fabrics have less variation than aged. The cotton fabric used for the soiling pretests was balanced plain-weave bleached cotton, 75 x 75 threads per in. This fabric was used for all pretests and trials 1 and 2.

New fabrics proved to be too resilient to test for displacement or damage and were replaced with naturally-aged cotton from a historic garment that dates to the first quarter of the 20th century. Trial 3, which focused on damage, used a child’s dress deaccessioned for conservation practice and experimentation from the URI Historic Textile and Costume Collection to the Textile Conservation Laboratory collection. The dress had been used in a student’s wetcleaning project that compared reducing bleaches—solutions of ionic and nonionic surfactants with either sodium dithionite or sodium borohydride. The high concentrations of bleach used weakened the textiles, which would make them more susceptible to damage from surface cleaning (Keefe 2016). Samples were cut from the garment and randomly assigned to treatments. The fabric was plain-weave bleached cotton, 96 x 84 threads per in.

2.2.2 Soil

Despite efforts to control museum environments, many collections are exposed to dust, soil, and atmospheric pollution. Visitors generate dust and fibers that settle on textiles on open display. Atmospheric pollution carries soot, a fine particulate that is difficult to remove from textiles. Smoke created by wildfires, building fires, and furnace puff-backs introduces quantities of soot into museum and historic site collections. Coarse particulates are effectively removed by vacuuming while most fine particulates remain on the surface (Yoon and Brimblecombe 2001). The small particulates require additional cleaning techniques, such as surface cleaning with sponges. Soot became the focus of this study due to the small size of the particulates.

Soot particulates range from 0.05 to 1.0 µm in size, though agglomerates of particles may be larger. The product of incomplete combustion of a fuel source, soot contains particulate carbon, oily components, and inorganic components. Though the composition and characteristics of soot vary by fuel source, particulate carbon generally accounts for 60% or less of the solid matter (Druzik and Cass 2000, 22). The limited controlled research of soot removal has used varying sources of soil. Previous experimentation of surface cleaning techniques used "dust collected from the cellar…and stored in a greasy environment," a kitchen (Daudin-Schotte, et al. 2012, 210). This collection method was used to test removal techniques on paintings that had accumulated soil over time. To produce more realistic smoke to test soot removal techniques on book covers, building fire conditions have been replicated using government fire safety testing laboratories (Silverman and Irwin 2009, 32). Neither method was deemed appropriate for the study.

In a study of the ability of humans to detect soot on paintings, soil deposition was modeled by printing carbon black dots over colored backgrounds (Bellan, Salmon and Cass 2000, 1947).[5] While it does not contain the additional material carried by smoke,

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[5]In an "edge-to-edge" comparison of soiled and clean samples, some observers could detect soil at 2.4% coverage while most observers could detect soil at 3.6% coverage." When soiled and clean samples are separated, soil is not accurately detected until surface coverage reaches 12% coverage (Bellan, Salmon and Cass 2000, 1946).

carbon black is a suitable analog for soot. Carbon black is produced under controlled settings so that 97%-99% of the solid matter is particulate carbon (Watson and Valbery 2010, 220-1). Cosmetic grade carbon black pigment was purchased from MakingCosmetics Inc. Prepared using the "oil furnace" process that uses aromatic petroleum oil, the particle size is 0.02 to 0.06 μm, replicating the smallest particulates found in soot (MakingCosmetics 2016). The carbon black was applied to the fabric using an accelerated soil tester with the method described in the following section.

2.2.3 Soiling

The method of soiling samples was based on AATCC Test Method 123-2000, Carpet Soiling: Accelerated Soiling Method. This method compares the soiling propensity of two or more carpets to measure "the ability of a carpet to be cleaned or the efficiency of a cleaning process" (AATCC 2007, 199). It includes simlulating the mechanical wear and soil deposited on carpets by normal foot traffic. The substrate for the carpet soiling test was changed to better represent non-pile textiles that might be damaged by smoke and soot during a fire disaster, discussed in section 2.2.1 Substrate. Samples are tumbled in a ball mill, a drum that alternates direction every two minutes to evenly distribute soil. Plain-weave cotton squares, 6.4 cm^2, rather than 18 x 9 cm carpet pieces as specified in the test method, were tumbled in the ball mill with carbon black..

Component particles in the recommended soil formulation are much bigger than soot, would act as unnecessary filler, and are not analogous with the solid components of smoke. Ingredients include peat moss, Portland cement, and kaolin clay, none of which occur in smoke or soot, and the formulation does not specify grade or particle size. One of the components is carbon black, which is used exclusively as a substitute for soot, as discussed in 2.1.1 Soil. Test trials determined the amount required to create even soiling to match descriptions and pictures of soot deposits in the literature. Batches of twenty fabric samples were placed in the accelerated soil tester with increments of 0.02 gm of carbon black and compared visually. One-tenth gram of carbon black per fifty fabric samples provided sufficiently soiling for the main study.

Test method 123 specifies a direct motor-driven jar mill; an accererated laboratory ball-mill soil tester was used—model CSI-79 availble from Custom Scientific Instruments, Inc.[6] The ball mill specifications stipulate using 0.5 in. (1.27 cm) diameter steel balls; the AATCC test method specifies 1.9-2.5 cm (0.8-1.0 in.) diameter flint pebbles. Both size balls were too damaging, leaving impressions on the surface of the fabric and did not evenly distribute the soil (fig. 1). Smaller steel balls, 0.25 in. (0.64 cm) diameter, better distributed the soil but still left impressions on the fabric surface (fig. 2). Two mm diameter glass beads evenly distributed the soil and left no noticable damage to the surface of the textile (fig. 3), so were used for the study. Ten grams of glass beads per 0.1 gm of carbon black were run with fifty cotton square samples in the ball mill for ten minutes. This ensured the most even distribution of soil, but does produce more impact force than soot carried by smoke.

[6] The accelerated soil tester in the Textile Testing Lab at URI is model CS 97 010. This model is no longer available; communication with the company determined that that newer model had comparable specifications. The newer model is discussed here, since a spec sheet could not be found for the model used.

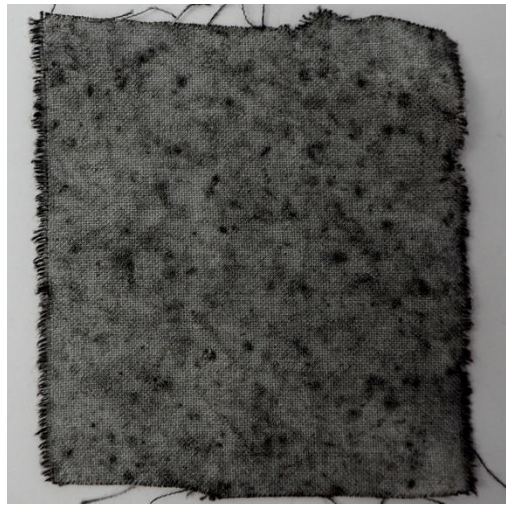

Fig. 1. Fabric soiled using 0.5 in. (1.27cm) diameter steel balls

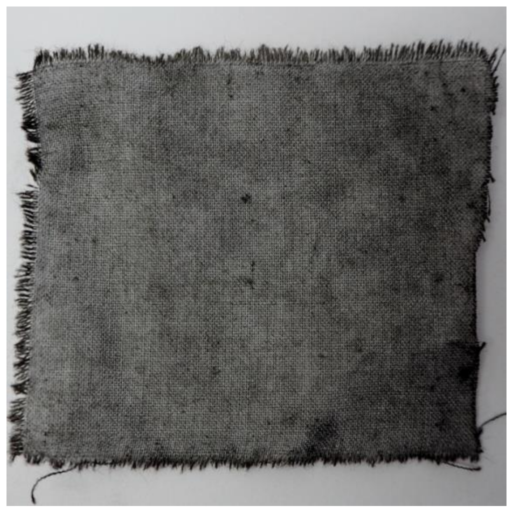

Fig. 2. Fabric soiled using 0.25 in. (0.64 cm) diameter steel balls

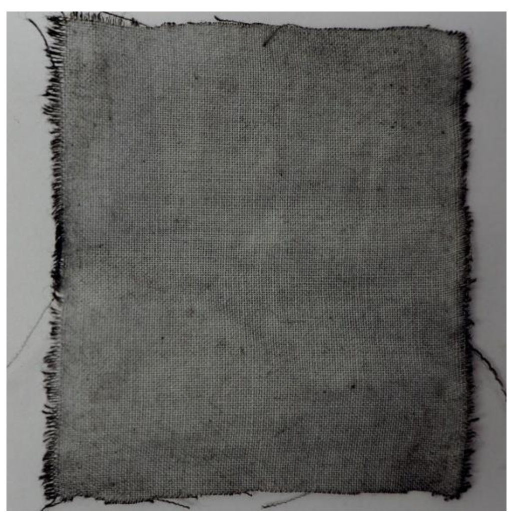

Fig. 3. Fabric soiled using 2 mm (0.08 in.) diameter glass beads

2.2.4 Mounting and Tagging

Touching soot-covered surfaces pushes the particulates between and into the yarns. To minimize the effects of handling, samples were removed from the drum, held by the edges outside of the testing area, pinned to individual foam board cards, and labeled (fig. 4).

While the soiling method chosen for the study was the most consistent at applying soil evenly, variations in the amount of carbon black deposited on the textile could be detected using a spectrophotometer. Measurements were recorded using a portable sphere spectrophotometer, X-rite model SP62 with Color iQC, version 7 software. After-treatment readings were compared to the same before-treatment sample control so that the variations between samples would not distort the results. To ensure that readings were taken in the same position, each sample was "tagged." A small dot, approximately 0.5 mm diameter, was drawn with a red pen on the sample mounted on a foam board. The tag was placed in the center of the testing area and centered in the target window of the spectrophotometer. Comparison of tagged and untagged spectrophotometer readings showed that the dot had no effect on the lightness measurement when it was included in the control reading before treatment. When multiple readings were taken of the same area, the untagged readings were less consistent as it was more difficult to reliably target the same area with the spectrophotometer. Cleaning efficacy was recorded as the change in lightness, ΔL, where L is the position on the lightness axis of the CIE L*a*b* color model.

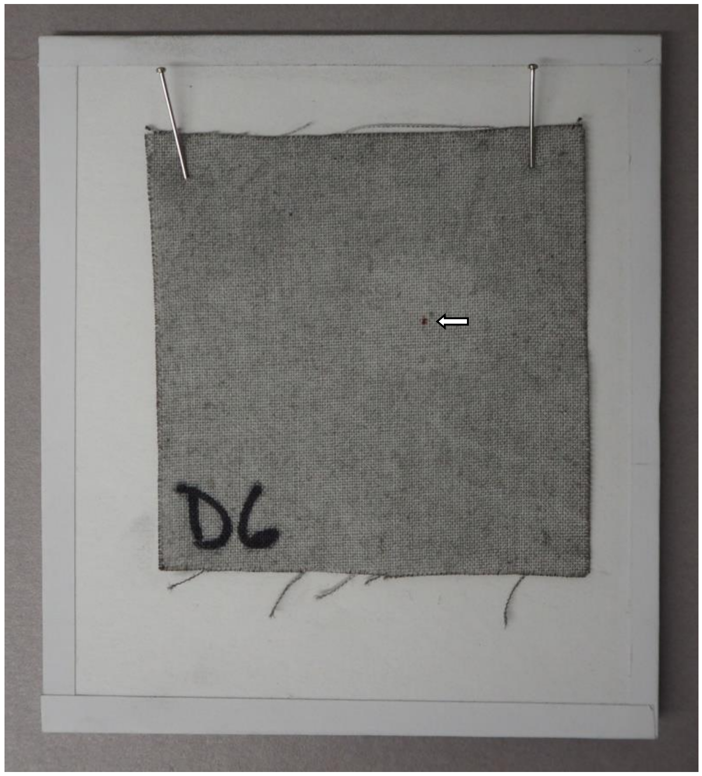

Fig. 4. Tagged sample pinned to foam board

2.3 TESTING PROCEDURE

2.3.1 Vacuuming

Although vacuuming is a common surface-cleaning technique, many published descriptions and instructions are vague or cannot be applied to soot removal. Common phrases used in case studies are “surface-cleaned using low-powered vacuum suction” (Lennard 2011, 496) or “surface cleaned with vacuum suction” (Gill and Eastop 2011, 304). Some publications describe the process by including other tools used with phrases like “surface cleaned on both sides using low powered vacuum suction applied through a monofilament screen” (Seth-Smith and Wedge 2011, 372). Some discussions suggest that the lowest effective suction level should be used, requiring some testing to determine the appropriate method for each object (Canadian Conservation Institute 2010). Suction level may be controlled by using a vacuum with an adjustable rheostat, changing the distance between the vacuum and the surface, or by modifying the vacuum attachment.

The commonly described method is to use a vacuum with low suction so that the textile is not damaged by the treatment and to use a hose attachment to work in small, controllable sections. Brush attachments are used to reduce suction or gently loosen soil from the surface. Screens are placed on top of a textile to prevent the object from getting caught in the hose, also offering a gentle method to hold down the object. When a textile is caught in the hose or "sucked up," the force of the suction can cause mechanical damage by pulling out yarns and distorting the weave structure. But, as touching sooty objects further embeds the soot, a screen should not be used directly against a soot-covered textile surface (Roberts, et al. 1988, Francis 1998). Screens may be attached to the end of the hose to prevent suck-up, when placing a screen directly on the object is inappropriate (Canadian Conservation Institute 2010, 2). Small scale tests were carried out to establish a repeatable method to be used in the main study. Carefully established standards would be beneficial for conservators' use and research.

Plain-weave cotton samples were prepared using the method discussed in Section 2.2.3 Soiling and pinned to a foam board mount. Using a Miele Galaxy™ Series S4210 Sirius canister vacuum cleaner set to the lowest suction setting available; four hose attachment configurations were tested— a plain hose, a screen-covered hose, an upholstery brush, and a screen-covered upholstery brush. Effects of the distance from the bottom of the hose to the surface were observed and documented.

In all cases, once the middle of the sample was pulled up towards the hose, the surface remained distorted. The surface could be partially re-flattened after vacuuming, though to do so required aggressive handling of the textile. The plain hose and the screen-covered hose started to pull the fabric up towards the hose opening at 1.5 cm. At that distance little soil was removed from the surface. Using the brush attachment alone did not pull the sample towards the hose until it was 1 cm away from the surface. The brush attachment covered with screen could get as close as 0.5 cm before distorting the surface, which was noticeably cleaner than those treated with the other three hose configurations.

The upholstery brush covered with fiberglass screen, attached with adhesive tape, was found to be the most effective and caused the least distortion of fabric. This configuration was then used to test the number of times the vacuum hose is passed over the surface to evenly remove the carbon black without distorting the testing surface. Each pass starts at the bottom of the sample and slowly moves over the testing area to the top of the sample, approximately 0.5 cm above the surface. Samples were compared using visual comparison of photomicrographs.

To avoid unnecessary treatment, the fewest number of effective passes was evaluated. One and two passes were visually very similar and showed little change in the amount of soil on the surface. Four passes removed soil unevenly, leaving patchy areas, and mostly removed soil from the loose yarn ends. Eight and sixteen passes looked very similar and evenly removed soil. Thirty-two passes caused the middle of the sample to distort, causing the fabric to not lay flat even with manipulation. The method established for further tests in the study was to vacuum the sample using eight passes of the vacuum cleaner hose. This provided the most even soil removal without distorting the surface of the fabric while leaving sufficient soil remaining to require further treatment.

2.3.2 Tamping

Paintings and object conservators rub, roll, or tamp sponges on a surface to remove soil. Textile conservators recognize that rubbing and rolling sponges across the textured surface of textiles will damage surfaces by displacing yarns, abrading fibers, and leaving sponge debris. Tamping, repeatedly pressing the sponge in place, is less damaging to textiles than rubbing or rolling the sponges.

When sponges are used to remove carbon black, they become less effective as soil accumulates in their cells. A small-scale test determined how long a sponge surface could be used before it became ineffective. One sponge was used for this test, University Products Dry Cleaning Sponge, selected to represent a standard based on published literature. Samples were prepared by the previously-outlined methods for soiling, mounting, and vacuuming. Using the spectrophotometer, lightness was measured after vacuuming and each cumulative set of tamps was compared to untreated sample measurements to establish the change in lightness (ΔLightness). As the change of lightness increases soil is being removed by the sponge, as that value decreases the particulates are being redeposited onto the surface (fig. 5).

Sponges quickly remove soil before their efficacy reaches a plateau, after which carbon black is redeposited onto the surface of the textile. While treating a sample, the area being treated is immediately lighter than the surrounding area, and carbon black is present on the surface of the sponge. Eight and sixteen tamps displayed a significant amount of cleaning (p=0.02) when compared to the untreated sample. After sixteen tamps particulates are redeposited onto the sample; redeposition gradually increases until the treated sample approaches the lightness value of the untreated sample. As no significant difference existed between eight and sixteen tamps, both were tested in trial 1.

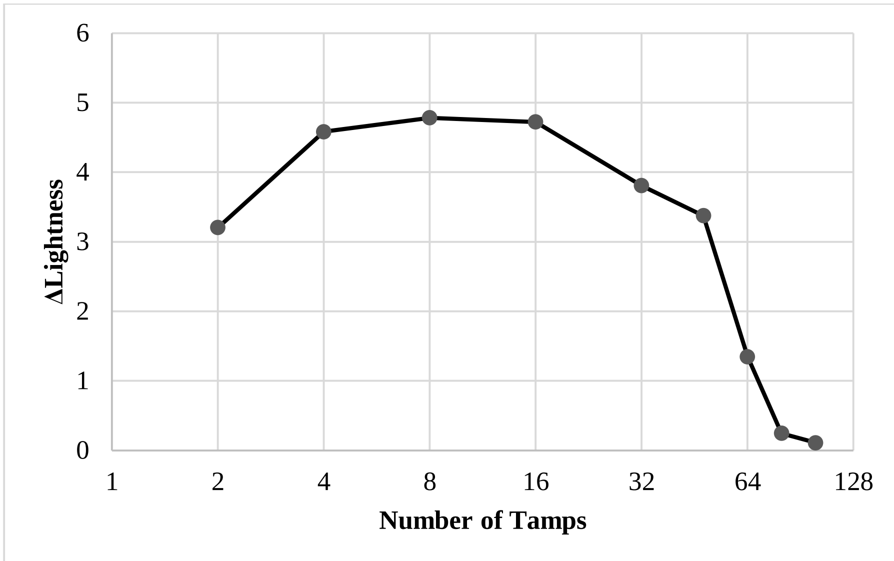

Fig. 5. Number of tamps, efficacy pretest

2.3.3 STATISTICAL ANALYSIS

For all trials that used spectrophotometer readings to determine the change in lightness, statistical analysis was completed using R, statistical computing software. Heteroscedastic, two-sample unequal variance, t tests with two-tailed distribution were used to analyze data, with α set at 0.05. Benjamini and Hochberg's false discovery rate was used to adjust multiple comparison of all pairwise comparisons between groups in Trial 2 (1995).

3.0 TRIALS

The study is broken up into a series of trials to test efficacy, identify damage, and measure residue and as a result established sponge-cleaning procedures. Trial 1 focuses on efficacy of the five selected sponges for the removal of carbon black from new plain-weave cotton. Trial 2 addresses the number of clean sponge surfaces needed to effectively remove soil. Trial 3 evaluates damage to aged textiles, in terms of dislodged yarn ends and yarn displacement in the weave structure. The five selected sponges were used in all trials: University Products Dry Cleaning Sponge (natural rubber), University Products Latex-Free Hydrophilic Sponge (polyurethane foam), Paint USA® K-42R Soot & Dirt Remover (natural rubber), Studio 35 Beauty™ Cosmetic Wedges (polyurethane foam), and up & up™ Latex-Free Foam Cosmetic Wedges (polyurethane foam). All trials used the methods outlined in the section 2, unless otherwise noted.

3.1 TRIAL 1: COMPARISON OF SPONGE EFFICACY

The main research question of the study was how well each sponge worked in comparison to the other sponge types or brands. Efficacy was measured as the change in lightness (ΔL) using a spectrophotometer. Lightness was recorded before treatment, after eight tamps, and after sixteen tamps; ΔL data were analyzed using R. The two tamp variations were chosen based on the tamping pretest, when the sponges are the most effective before the sponges start to redeposit soil onto the surface. In addition to the spectrophotometer measurements, photomicrographs were taken of the treated samples with the stereo light microscope before treatment and after sixteen tamps. The difference between the cleaning efficacies of each sponge as demonstrated in the photomicrographs are subtle, making visual comparison unreliable and impractical.

3.2 TRIAL 2: NUMBER OF CLEAN SPONGE SURFACES

Since sponges have limited capacity to hold soil before it is redeposited onto the surface of a textile, using more than one clean sponge might be necessary to suitably clean a soot-covered object. As there was no significant difference between the number of tamps tested in Trial 1, the number of tamps was changed to simplify the procedure. Each sponge was tamped ten times before it was considered too dirty to be effective. Lightness was recorded with a spectrophotometer before treatment and after treatment with one, two, three, and four clean sponge surfaces. Changes in lightness were statistically analyzed with R. The trial was used to establish a recommended treatment method along with determining the number of tamps required for trials 3 and 4, simulating a “normal” treatment.

3.3 TRIAL 3: DAMAGE TO AGED TEXTILES

Damage was not detected on the new cotton used for trials 1 and 2. As discussed in Section 2.2.1 Substrate, the test samples were replaced with more fragile cotton from a historic garment. Building on information collected in the previous trials, each sample was tamped with two sponge surfaces, ten times each. The trial was divided into two sections, each representing a type of damage. Both sections were measured by comparing before treatment and after treatment photomicrographs. Part A defined damage as fiber ends pulled out of yarns or yarns pulled out of the weave structure. This was determined by counting fiber ends viewed along a 0.5 cm fold and analyzed with R. Part B defined damage as yarn displacement within the weave structure. This was determined by digitally laying the after treatment photo over the before treatment photo and comparing the yarn alignment. Displacement was measured as the percent change of each yarn as compared to the untreated sample.

3.4 TRIAL 4: RESIDUE

Sponge residue remaining on the surface of treated textiles is an additional concern for conservators. Small crumbs of the sponges or additives such as calcium carbonate may be dislodged and left on the textile. In addition to the mechanical damage caused by small particulates left between yarns or fibers, the degradation of polyurethane, natural rubber, and the additives could produce harmful acidic or alkaline conditions over time. Oxidation of vulcanized natural rubber can lead to the production of sulphuric acid (Loadman 1993, 68). Polyurethane foams also are vulnerable to oxidative degradation and have been found to leave acidic compounds and glycol derivatives, the effects of which have not been evaluated (Lattuati-Derieux and Thao-Heu 2011, 4507). Debris left on the textile during the cleaning process could promote future damage to the object.

Residue could not be identified with the stereo microscope used to visually evaluate the effects of using sponges to clean textiles. To isolate the potential residue, the sponges were tamped on glass slides, dry mounted, and compared using a polarizing light microscope, Olympus® BH2 with Nikon® Digital Sight DS-Fi1 camera. For each sponge brand repetition the tamped area was sampled three times to establish a representative residue. The particulates were measured and counted to produce average debris left by the sponge. Small particulates could be seen on treated samples with the higher magnification of the scanning electron microscope (SEM) using backscatter electron imaging (BEI), but the composition of particulates, whether they were debris, dust, or other contaminants, was not evaluated.

4.0 RESULTS AND DISCUSSION

4.1 SPONGE CHARACTERISTICS

Two types of sponges are used for surface cleaning by conservators—vulcanized natural rubber and polyurethane foam. In selecting sponges for the main trial it became clear that although sponge types appear similar there are many differences between brands (table 1). While some characteristics of the five selected sponges overlap, variations of composition and structure are represented. Composition includes manufacturer or retailer listed materials as well as EDS identification of additives. Structure includes cell size, firmness, and other physical characteristics. In addition to the structural and compositional characteristics, brand, commercial name, and source are provided in the table.

Natural rubber sponges chosen for the study include University Products Dry Cleaning Sponge (figs. 6-8) and Paint USA® K-42R Soot & Dirt Remover (figs. 9-11). White structures present on the SEM photomicrographs for both sponges were identified by EDS as mostly calcium, which is consistent with the additive calcium carbonate. Fillers used in rubber production reduce costs, reinforce materials, or alter physical properties. Common filler materials for vulcanized rubber include "calcium silicate, calcium carbonate and clay" (Azrem, Noriman and Razif 2013, 876). Both natural rubber sponges are marketed to remove soot and smoke damage. Small variations between cell sizes are likely due to sponge structure and random sampling. No discernible difference between the firmness of the two natural rubber sponges was detected. The most notable difference between the two brands are the sources, University Products is a conservation supply company marketing their products to conservators and museum professionals while Paint USA® sponges are a widely available commercial product intended for general use.

Table 1. Sponge Characteristics

Commercial Name	Source*	Composition	Cell Size Range (mm^2)	Average Cell Size (mm^2)	Cells per cm2	Firmness
Paint USA® K-42R Soot & Dirt Remover	ACE Hardware	Natural rubber, calcium carbonate	0.17-0.89	0.46	132	--
University Products Dry Cleaning Sponge	University Products online or catalog only	Natural rubber, calcium carbonate	0.15-0.98	0.48	134	--
Studio 35 Beauty™ Cosmetic Wedges	Walgreens	Polyurethane foam, calcium carbonate	4.9×10^{-4}-0.027	6.7×10^{-3}	8000	Medium
up & up™ Latex-Free Foam Cosmetic Wedges	Target	Polyurethane foam	0.012 -0.053	0.031	2300	Soft
University Products Latex-Free Hydrophilic Sponge	University Products online or catalog only	Polyurethane foam, aluminosilicate, titanium oxide	1.2×10^{-3}-0.026	7.8×10^{-3}	6600	Firm

*Source reflects the location that sponges for this study were purchased. All sponges purchased in stores were also available online from either the vendor's website such as Target.com or through online retailers such as Amazon.com.

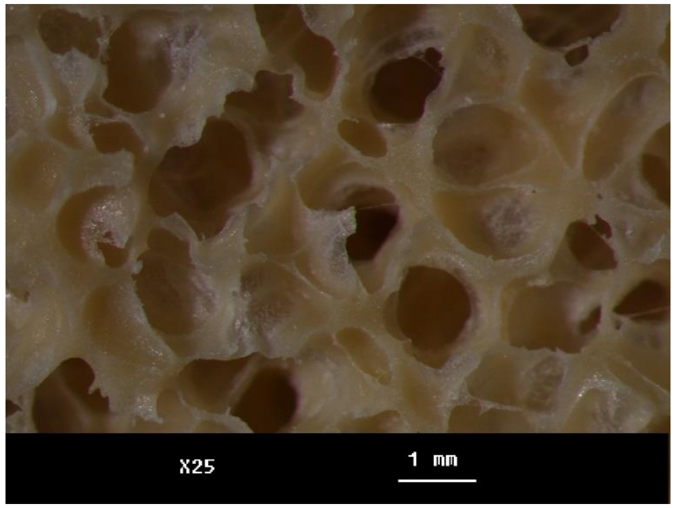

Fig. 6. University Products Dry Cleaning Sponge, stereo microscope

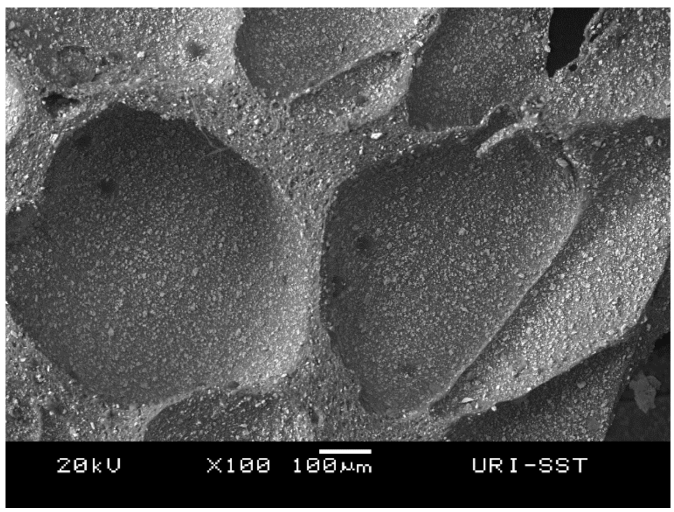

Fig. 7. University Products Dry Cleaning Sponge, SEM

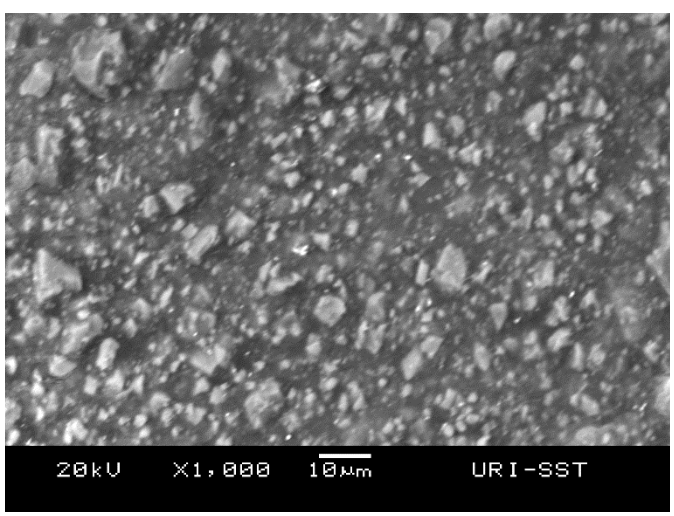

Fig. 8. University Products Dry Cleaning Sponge, SEM

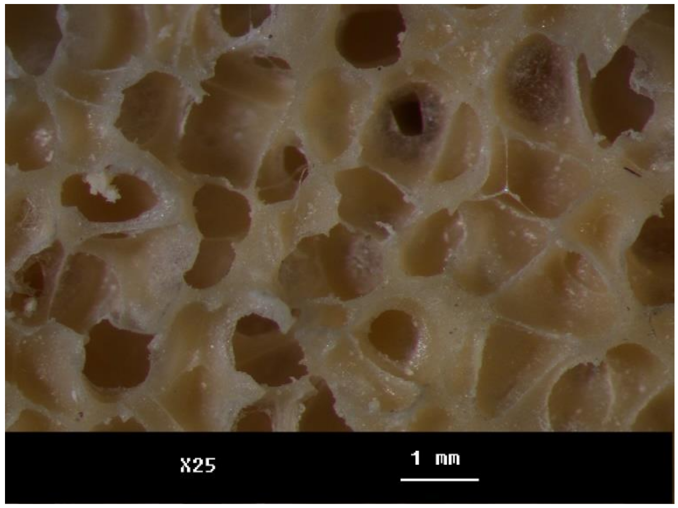

Fig. 9. Paint USA® K-42R Soot & Dirt Remover, stereo microscope

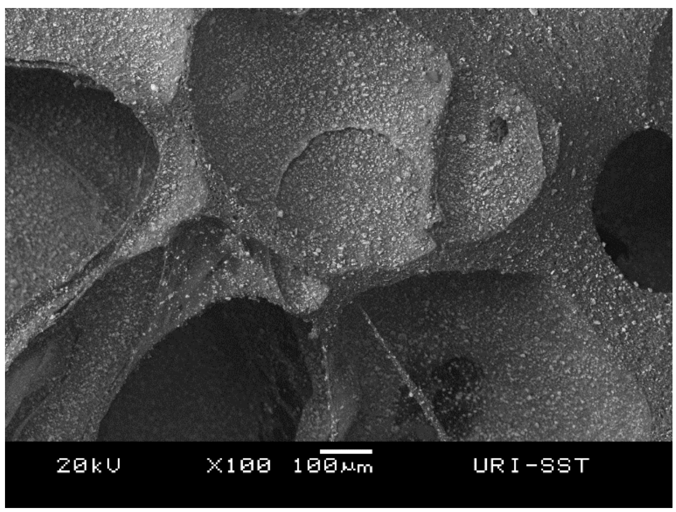

Fig. 10. Paint USA® K-42R Soot & Dirt Remover, SEM

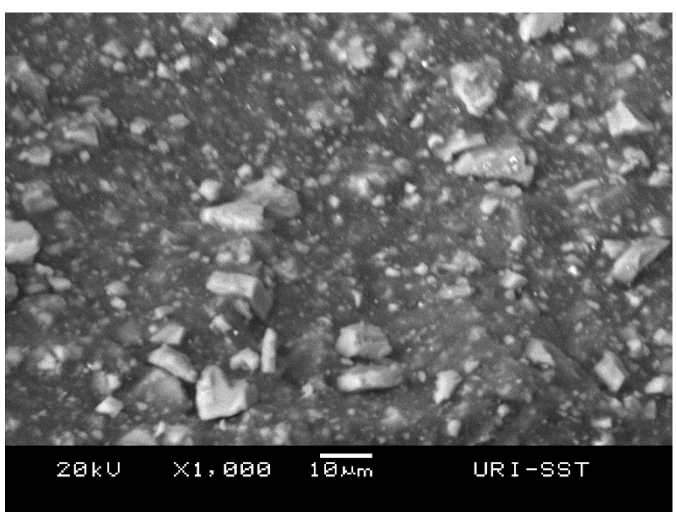

Fig. 11. Paint USA® K-42R Soot & Dirt Remover, SEM

Polyurethane foam sponges selected for trials included University Products Latex-Free Hydrophilic Sponge (figs. 12-14), Studio 35 Beauty™ Cosmetic Wedges (figs. 15-17), and up & up™ Latex-Free Foam Cosmetic Wedges (figs. 18-20).[7] Commercially available cosmetic sponges do not appear to have standardized characteristics; all sponges examined had slightly different cell structure or composition.

Rough categorization of sponge cell types was made by visual examination. The two small-cell sponges were very similar but the Studio 35 Beauty™ sponge had a wider range of cell sizes than the University Products polyurethane sponge. Small-cell sponges had the smallest cells but the greatest variation in cell size while the large-cell up & up™ sponge had comparatively larger cells with less variation in pore size.

Polyurethane foam contains fillers, such as aluminosilicate, titanium oxide, and zinc oxide, to reduce cost and improve physical properties (Scholz, et al. 2002,). Some cosmetic sponges contain skin conditioning additives such as Vitamin E, advertised for the Studio 35 Beauty™ sponge. These additives are designed to be released on contact with water, so may not be transferred to textiles during surface cleaning (Celia 1998). Small particulates are visible on the University Products sponge, deeply embedded in the surface. EDS analysis identified titanium, silicon, and aluminum, suggesting the possible presence of aluminosilicate and titanium oxide. Crystalline shards litter the surface of the Studio 35 Beauty™ sponge; particulates identified by EDS analysis are calcium indicating the presence of calcium carbonate as a filler. The up & up™ sponge had no visible additives.

[7] Sponge surfaces were darkened with ink, using a black felt tip pen, to increase the visibility of the individual cells for photomicroscopy.

The firmness of polyurethane foam sponges does not appear to relate to the number or size of cells. Each of the three selected sponges represent different levels of firmness—soft, medium, and firm. The up & up® sponge is easily flattened and offers little resistance when compressed, putting it in the soft category. The Studio 35 Beauty™ sponge has a medium level of firmness, between that of the two other brands. The University Products sponge is firm and is resistant to compression.

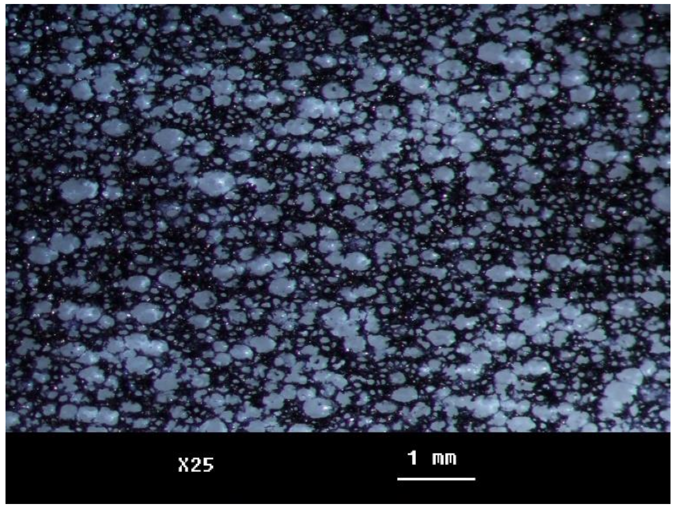

Fig. 12. University Products Latex-Free Hydrophilic Sponge, stereo microscope

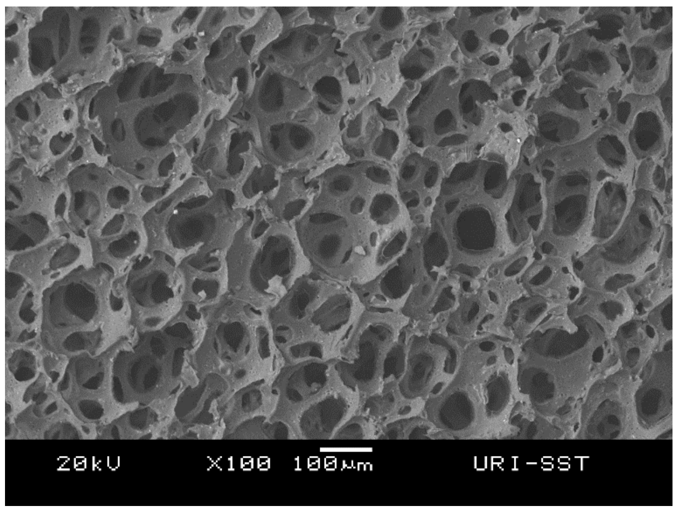

Fig. 13. University Products Latex-Free Hydrophilic Sponge, SEM

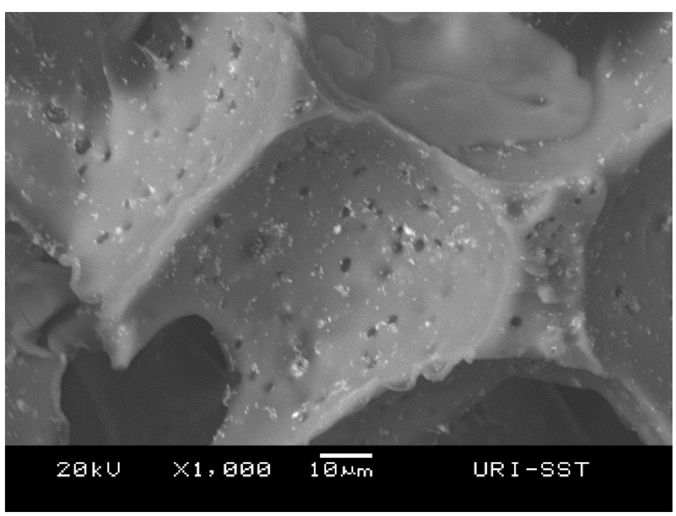

Fig. 14. University Products Latex-Free Hydrophilic Sponge, SEM

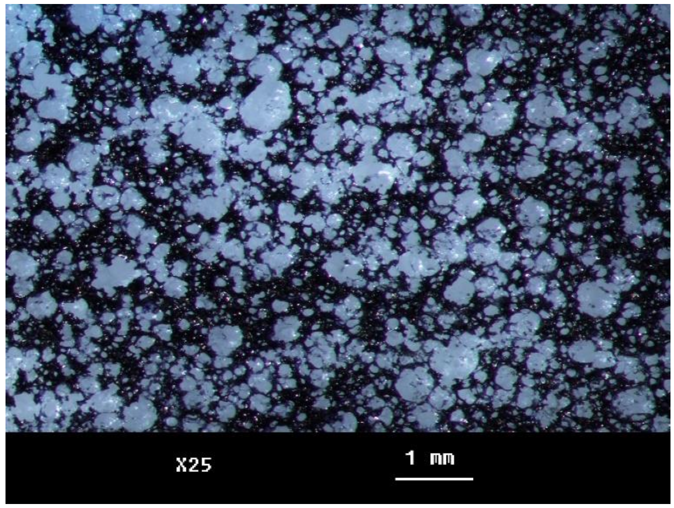

Fig. 15. Studio 35 Beauty™ Cosmetic Wedges, stereo microscope

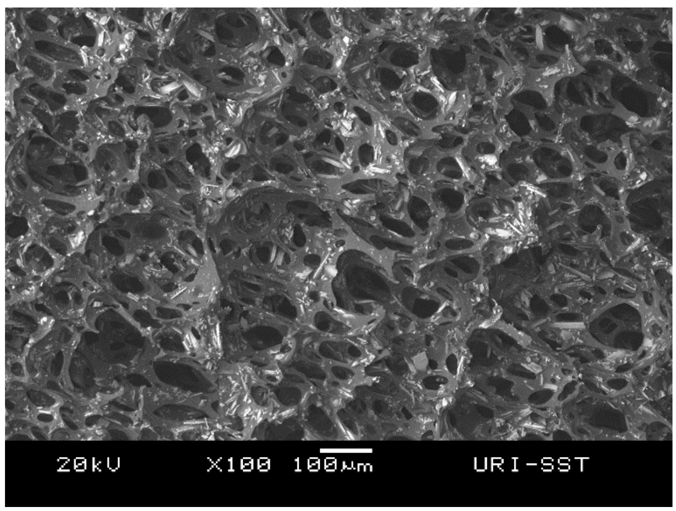

Fig. 16. Studio 35 Beauty™ Cosmetic Wedges, SEM

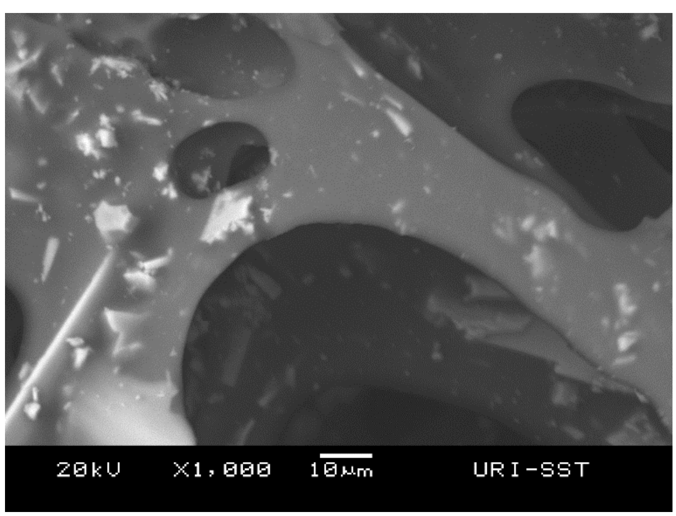

Fig. 17. Studio 35 Beauty™ Cosmetic Wedges, SEM

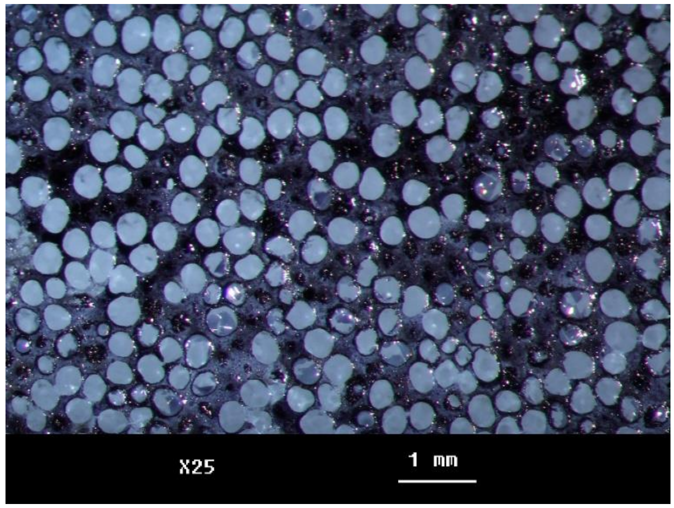

Fig. 18. up & up™ Latex-Free Foam Cosmetic Wedges, stereo microscope

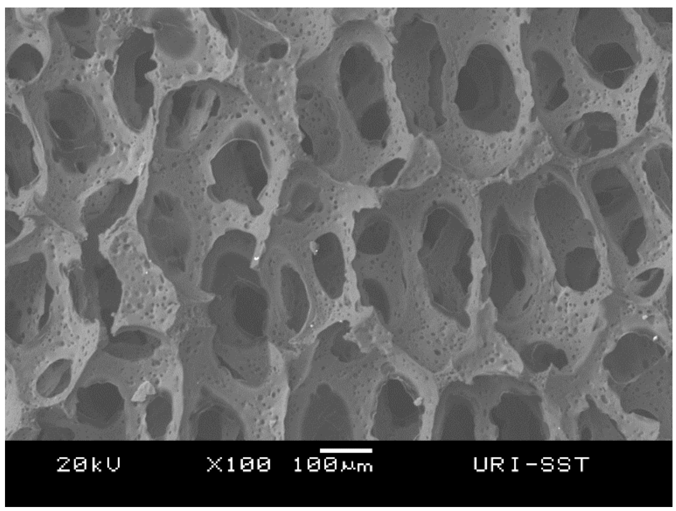

Fig. 19. up & up™ Latex-Free Foam Cosmetic Wedges, SEM

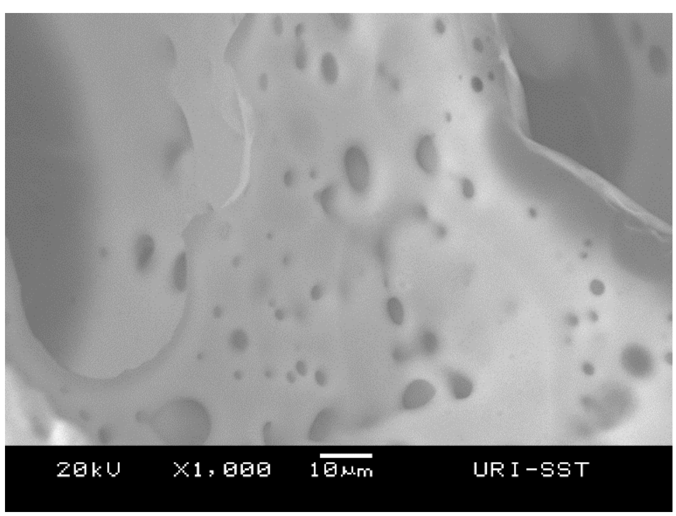

Fig. 20. up & up™ Latex-Free Foam Cosmetic Wedges, SEM

4.2 TRIAL 1: COMPARISON OF SPONGE EFFICACY

Guided by the results from the number of tamps pretest, described in Section 2.3.2 Tamping, Trial 1 tested the efficacy of both eight and sixteen tamps per sponge. No significant difference ($p > 0.3$) exists between the ΔL of eight and sixteen tamps for each sponge. This suggests that the number of tamps between the two tested variations are also insignificant. Ten tamps per sponge were used in Trials 2, 3, and 4 to simplify the discussion and testing.

As no significant difference was detected between eight and sixteen tamps, only the data collected after sixteen tamps were analyzed and reported (fig. 21). The Studio 35 Beauty™ sponge was marginally more effective than the Paint USA® sponge ($p < 0.04$) and significantly more effective than all other sponges ($p < 0.003$). The Paint USA® sponge was marginally more effective ($p < 0.04$) than natural rubber sponge from University products and significantly more effective ($p < 0.03$) than the up & up® sponge. The other three sponges were not significantly different. While one brand of polyurethane foam sponge, Studio 35 Beauty™, performed significantly better than all other sponges, all polyurethane foam sponges were not better than all natural rubber sponges. Brand characteristics are more important than material in choosing a sponge to remove particulate soil.

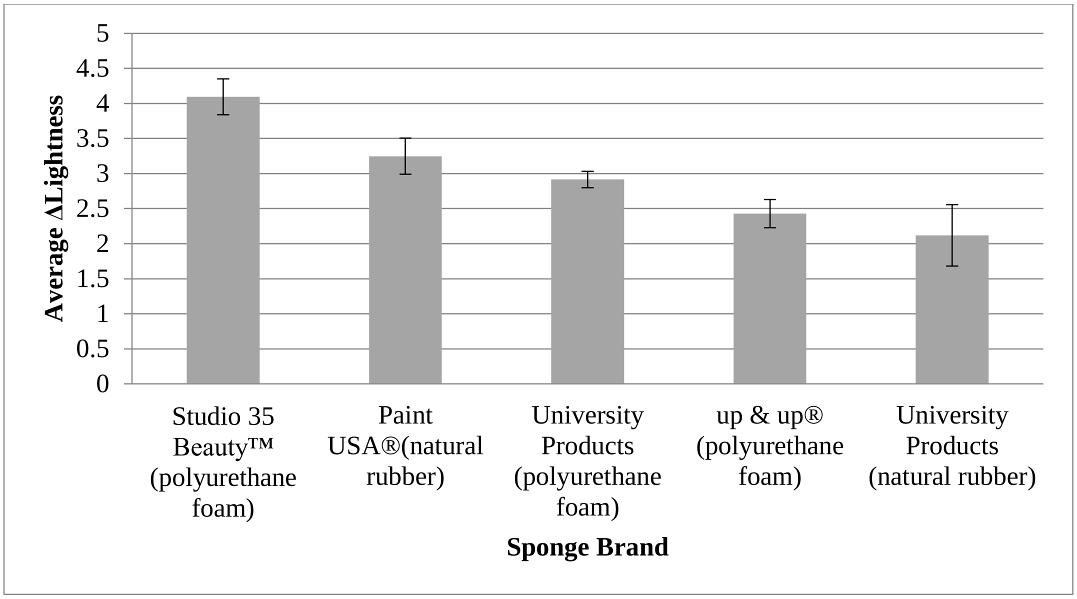

Fig. 21. Efficacy trial, average ΔL of sixteen tamps, (n=9)

4.3 TRIAL 2: NUMBER OF CLEAN SPONGE SURFACES

Sponges become less effective as they accumulate soil; using multiple clean sponges increases the amount of soil that may be removed. Each subsequent clean sponge removes less soil than the previous sponge, until it reaches a threshold of cleanliness where no additional soil is removed. While this trail does not focus on sponge efficacy, the results confirm the trends reported in Trial 1 (fig. 22).

After the use of three clean sponge surfaces both natural rubber sponges passed their threshold of cleanliness and the change in lightness decreased, though no significant difference is present between the use of three and four clean sponge surfaces ($p > 0.2$). The University Products natural rubber sponge and the up&up® polyurethane begins to reach its limit of effectiveness after two sponges, as each clean sponge surface fails to produce a significant change ($p>0.06$). For the other polyurethane sponges, Studio 35

Beauty® and University Products polyurethane sponge, each additional clean sponge surface removed significant amounts of soil (p<0.004).

As demonstrated in Trial 1, the Studio 35 Beauty™ sponge is significantly better than all other sponges. The slope of the ΔL for the all polyurethane foam sponges suggests that the more sponges may continue to remove soil; a significant amount of soil was removed by each subsequent sponge ($p < 0.003$). The sponges with the greatest cleaning efficacy removed approximately the same quantity of carbon black with two sponges as the sponges with the least cleaning efficacy removed with four sponges. Trial 3, evaluating damage to aged textiles, tested both two and four sponges to examine this cleaning overlap.

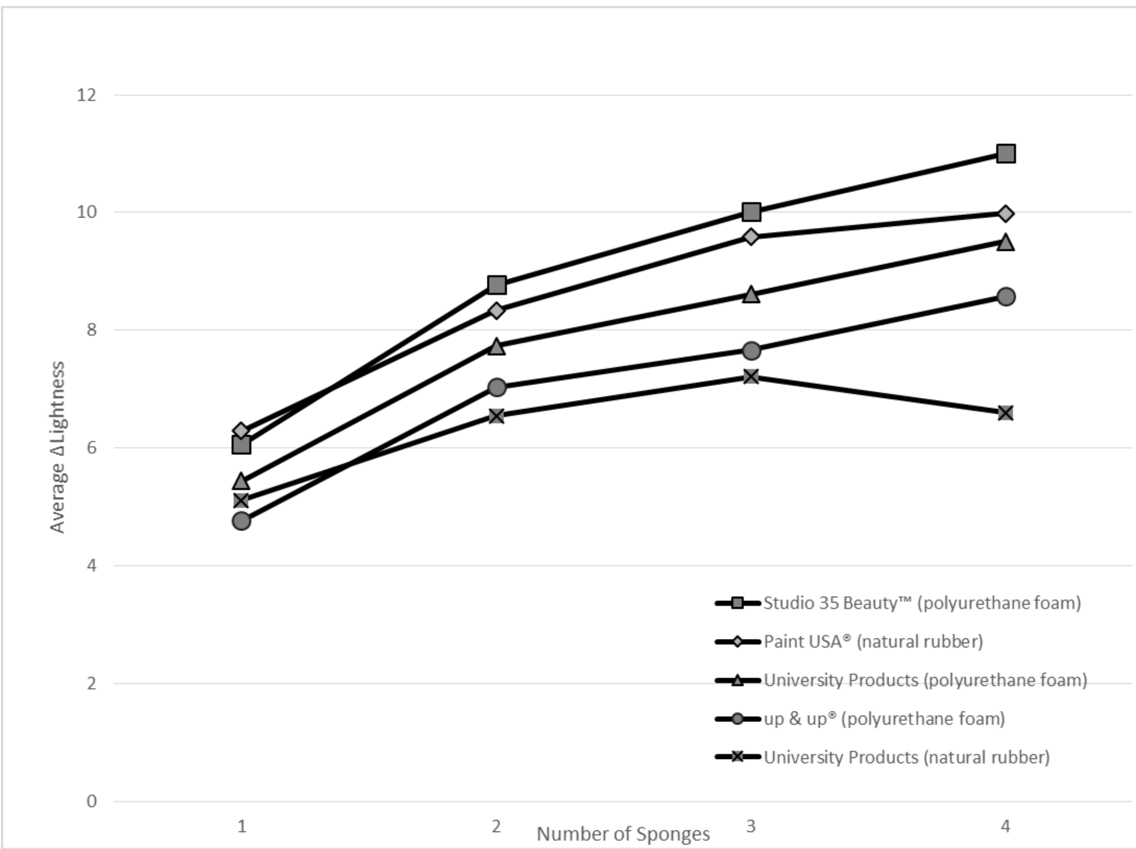

Fig. 23. Number of clean sponge surfaces, ΔLightness from comparison to untreated sample

4.4 TRIAL 3: DAMAGE TO AGED TEXTILES

Damage to aged textiles was evaluated through two parameters—the displacement of yarns within the weave structure and the quantity of fibers dislodged from the yarns.

4.4.1 TRIAL 3A: DISPLACEMENT OF YARNS

Displacement of yarns was categorized into four categories—little to no displacement (0-25%), minor displacement (25-50%), moderate displacement (50-75%), and major displacement (75-100%). The number of tamps to represent two and four sponges, twenty and forty tamps respectively, were applied and compared. Stacked bar charts display the percentage of yarns in each displacement category per sponge type (figs. 23, 24). Comparison of the two charts shows that more tamping displaces more yarns, but the most damaging sponge only displaced 13% of yarns, most of which shifted less than 25% of the yarn width. This shift of less than 0.01 mm could just as easily occur during normal handling. The most effective sponge identified in Trials 1 and 3, Studio 35 Beauty™, also does the most damage. Tamping increases the amount of disturbed threads; tamping more than forty times eventually could produce notable damage.

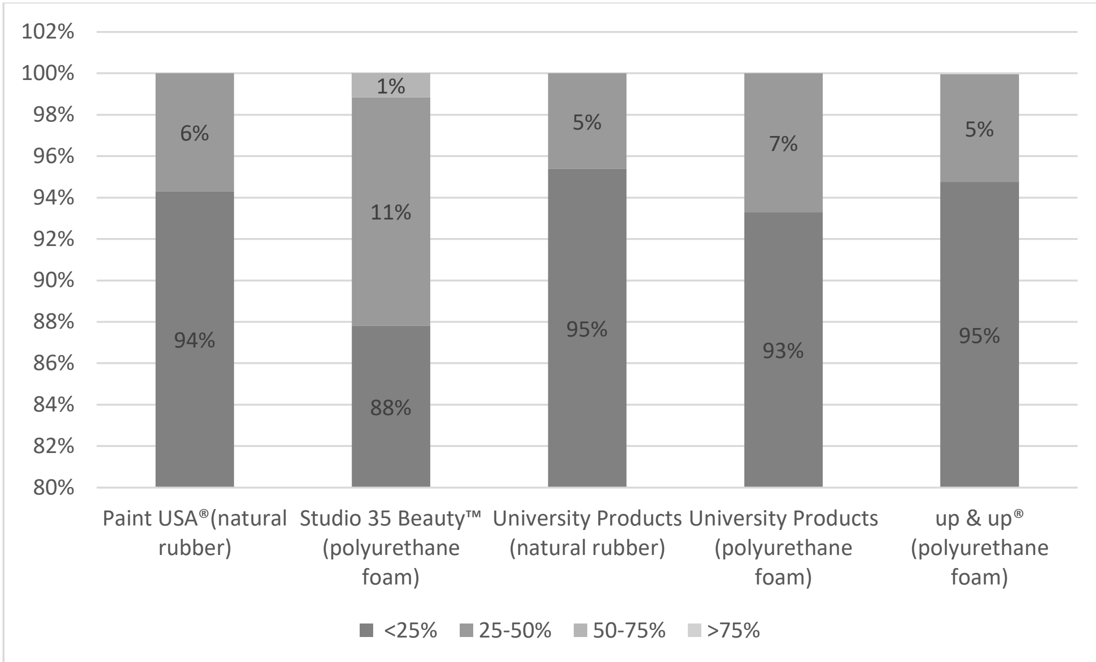

Fig. 23. Average displacement of yarns, 2 sponges

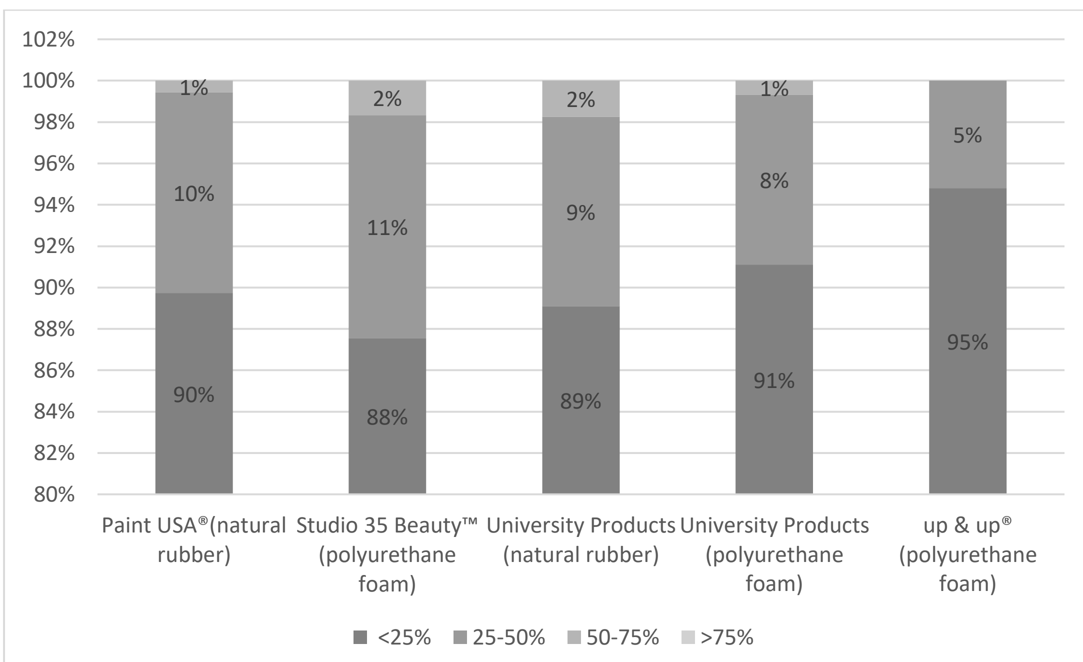

Fig. 24. Average displacement of yarns, 4 sponges

4.4.2 TRIAL 3B: DISPLACEMENT OF FIBER ENDS

Rather than fiber ends becoming dislodged during treatment, tamping with sponges reduced the number of fiber ends along a 0.05 cm fold. The mechanical action of pressing a sponge down onto a textile surfaces pushes the fibers flat. The number of clean sponge surfaces used, or total number of tamps, significantly reduces (p<0.003) the number of fiber ends sticking out. No significant difference (p>0.3) exists between sponge brands. On average, tamping with sponges reduced the fiber ends sticking out of the yarns by 20-30% (fig. 25).

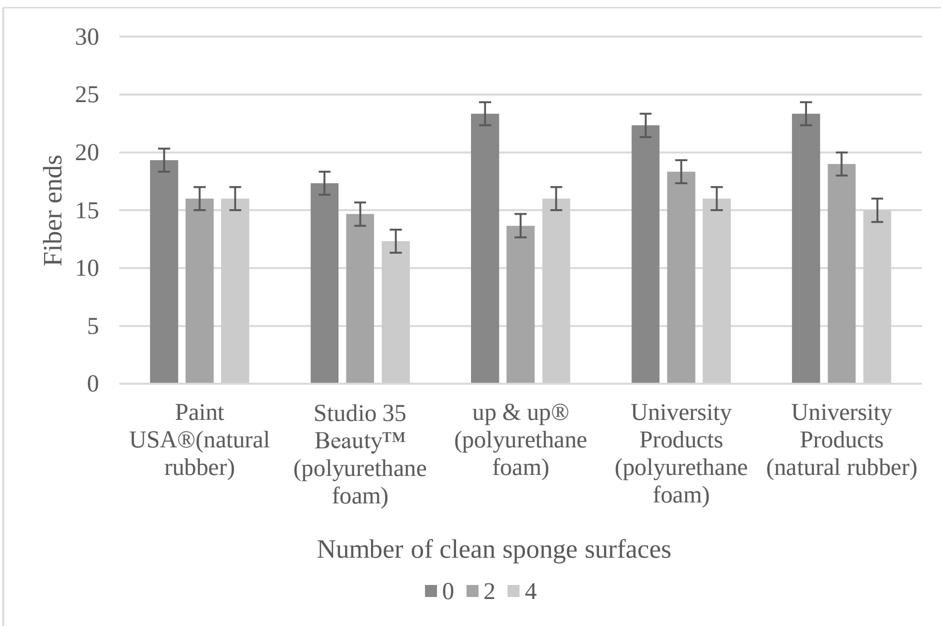

Fig. 25. Number of fiber ends stick out along a 0.5 cm fold

4.5 RESIDUE

Debris is left behind on surfaces after tamping a sponge. The smallest pieces of debris, for all tested sponges, were less than 1 micron, comparable in size to the carbon black the sponges are meant to remove (Table 2). Both natural rubber sponges left an alarming quantity of debris along with what appeared to be an oily residue (figs. 26, 27). The debris appeared to be both calcium carbonate filler and pieces of sponge.

TABLE 2: Debris Size and Quantity

Sponge	Debris size μm^2	Debris count per 20 mm^2
Studio 35 Beauty™ (polyurethane foam)	<1-44	27
up & up® (polyurethane foam)	<1-118	69
University Products (polyurethane foam)	<1-105	70
University Products (natural rubber)	<1-350	522
Paint USA®(natural rubber)	<1-254	622

All polyurethane sponges left debris. The Studio 35 Beauty™ sponge left the least debris, primarily crystalline fragments most likely calcium carbonate filler (fig. 28). Debris present after tamping the University Products polyurethane foam was not clearly any material, but more consistent in shape with the sponge pieces than crystalline filler (fig. 29). The up & up® sponge did not have any visible fillers or additives, suggesting that all debris were pieces of sponge (fig. 30).

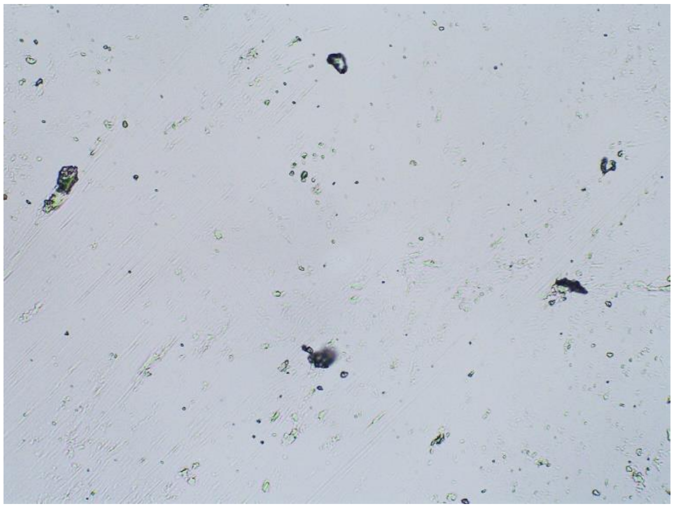

Fig. 26. Paint USA® sponge debris

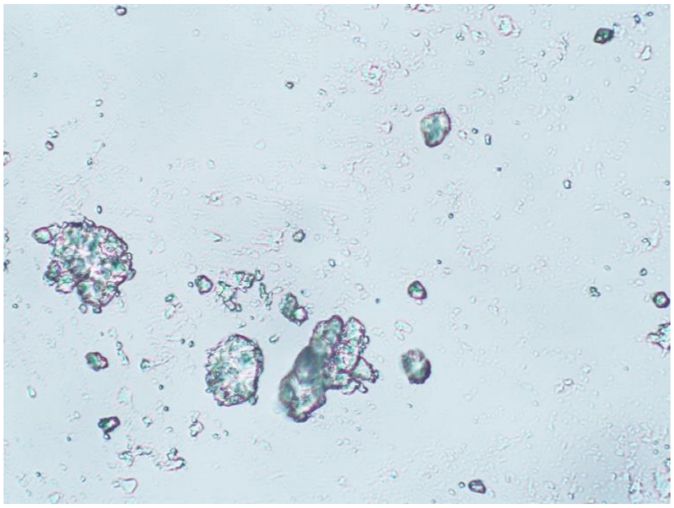

Fig. 27. University Products natural rubber sponge debris

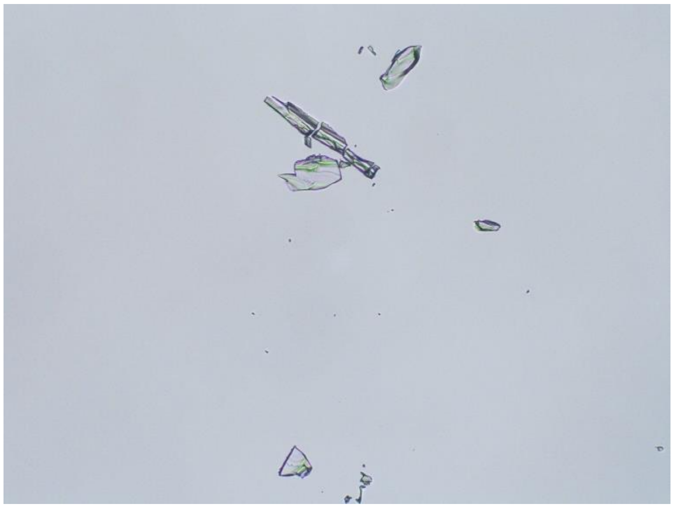

Fig. 28. Studio 35 Beauty™ calcium carbonate debris

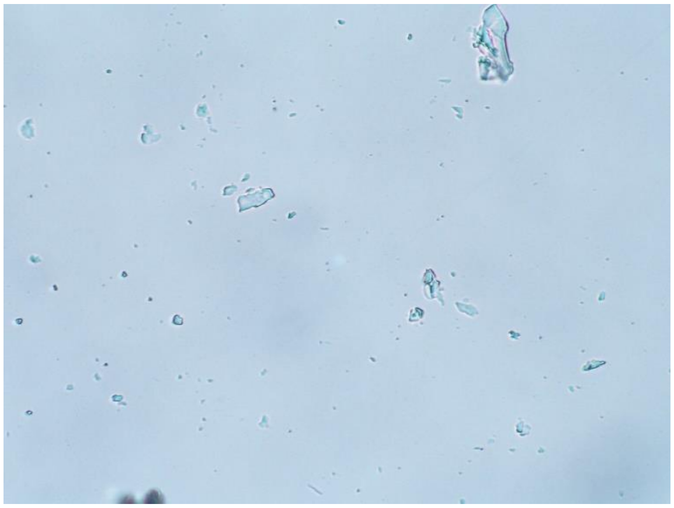
Fig. 29. University Products sponge debris

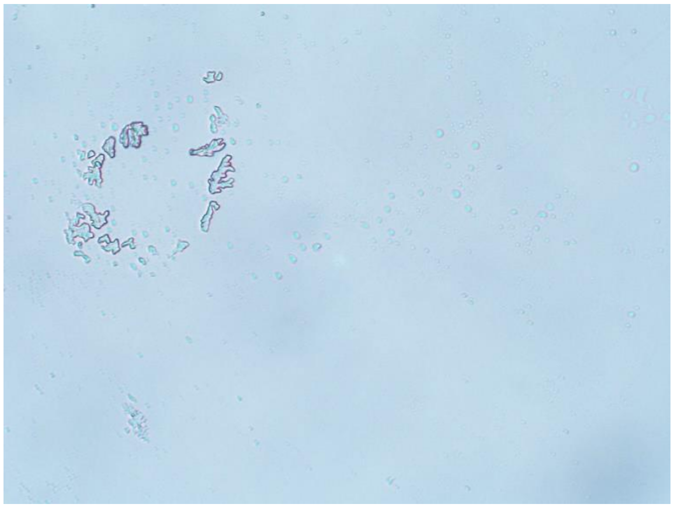
Fig. 30. up & up® sponge debris

5.0 CONCLUSIONS

Overall the Studio 35 Beauty™ was the best sponge; it was most effective at soil removal and the most effective with the least number of sponges. While it does displace a slightly higher percentage of yarns within the weave structure than the other sponges, the displacement is minor—less than half of the yarn width. The small quantities of debris left after tamping are unlikely to be removed by vacuuming due to their small size. On cellulosic fabrics, the calcium carbonate filler left behind may be inconsequential, though protein fibers might be more sensitive to the alkaline material. This sponge brand is the most effective with the least risks.

Polyurethane foam sponges did not universally perform better at efficacy tests than the natural rubber sponges. However the large quantities of residue left by the natural rubber sponges are enough to discontinue the use of this type of sponge entirely. The particle size of the residue is comparable to the carbon black, too small to be removed by vacuuming which is why sponges are being used for surface cleaning in the first place. It is probable that the treatment will leave as much residue behind as soil removed. Natural rubber sponges are not sufficiently effective or less damaging to offset the residue left behind.

In all tests the commercially available products were more effective and less damaging than the sponges purchased from a conservation supply company. Commercially available products are generally cheaper and more convenient to obtain. The fillers in the University Products polyurethane foam sponge are less likely to affect the pH of a textile than those found in the Studio 35 Beauty™ sponge. Commercially available sponges that use calcium carbonate or other alkaline fillers may be no worse than using buffered tissue for storage—acceptable for cellulosic fibers but not recommended for protein fibers. Neither source discloses the exact composition of their products, meaning that changes in formula could happen without anyone noticing.

7

5.1 FURTHER RESEARCH

This study clearly demonstrates the necessity of developing standard procedures and test methods for evaluating dry-cleaning sponges. Published materials discussing cleaning techniques are largely parts of case studies with little focus on controlled testing of methods. Suggested research topics for controlled testing include soil selection, soil application, and vacuuming procedures. Continued testing of sponges will be required as product availability changes and manufacturers alter the composition and structure of their products, particularly since the best brand is a commercially available cosmetic sponge.

The following topics are recommended for further study: amount and composition of additives present in sponges and their potential for damaging textiles over time; effect of rinsing sponges before use to remove or reduce unfixed additives; effect of rising on efficacy and debris left behind; amount and composition of debris remaining after treatment, along with how it might damage textiles over time; efficacy of using sponges to remove soot from fabrics with varying fiber contents and construction—particularly the presence and length of floats in a weave structure; efficacy of using sponges to treat soot deposits in combination with wet or solvent cleaning.

APPENDIX

Data and Analyses

LIST OF TABLES

Sponges were randomly assigned a letter during testing, data collection, and analysis to reduce user bias during the trials. As the sponge names are lengthy, they have retained their assigned letters in the following tables. Significance levels for all statistical tests were set at α<0.05.

2.3.2 TAMPING PRETEST

TABLE 1A. Sponge Name Key.

Sponge Brand	Label
Paint USA® K-42R Soot & Dirt Remover (natural rubber)	A
Studio 35 Beauty™ Cosmetic Wedges (polyurethane foam)	B
University Products Dry Cleaning Sponge (natural rubber)	C
University Products Latex-Free Hydrophilic Sponge (polyurethane foam)	D
up & up™ Latex Free Foam Cosmetic Wedges (polyurethane foam)	E

TABLE A2. ΔLightness Measurements for Variable Number of Tamps with Repetitions (n=3).

Rep	Number of tamps (Δlightness)									
	0	2	4	8	16	32	48	64	80	100
1	0	5.63	6.89	6.3	6.09	no data	5.05	1	1.32	0.83
2	0	2.14	3.9	3.88	3.62	3.02	1.92	0.61	-0.55	-0.91
3	0	1.84	2.96	4.17	4.46	3.7	3.15	2.43	-0.03	0.41
mean	0	3.20	4.58	4.78	4.72	3.36	3.37	1.35	0.25	0.11
stdev	0	2.11	2.05	1.32	1.26	0.48	1.58	0.96	0.97	0.91

TABLE 3A. Single Factor ANOVA Results,
Analysis of ΔLightness Measurements in Table 2A.

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between groups	103.79	9	11.53	6.35	0.00036	2.42
Within groups	34.5	19	1.82			
Total	138.29	28				

2.3.2 TAMPING PRETEST (cont.)

TABLE 4A. Paired Two-Tailed T-Test Analysis of ΔLightness Measurements in Table 2A. Significant *p*-values noted with asterisk (*)

Number of Tamps	*P*-value
2	0.12
4	0.06
8	0.02*
16	0.02*
32	0.06
48	0.07
64	0.14
80	0.7
100	0.85

4.2 TRIAL 1: COMPARISON OF SPONGE EFFICACY

TABLE 5A. ΔLightness Measurements for Efficacy Comparison Between Sponge Brands, with repetitions (*n*-9).
Outliers due to spectrophotometer user error have been removed.

Rep	**Sponge brand (Δlightness)**				
	A	**B**	**C**	**D**	**E**
1	2.87	3.46	2.65	3.31	1.96
2	1.54	3.04	0.31	2.84	3.19
3	3.15	4.66	2.27	3.17	2.42
4	3.53	no data	2.2	2.86	2.42
5	3.93	4.35	0.27	2.5	no data
6	3.21	3.26	3.55	3.23	2.1
7	3.77	4.14	1.04	2.67	1.83
8	4.2	4.72	3.79	2.37	3.48
9	3.03	5.13	2.99	3.29	2.03
mean	3.25	4.1	2.12	2.92	2.43
stdev	0.78	0.76	1.31	0.35	0.6

TABLE 6A. Single Factor ANOVA Results,
Analysis of ΔLightness Measurements in Table 5A.

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between groups	19.69	4	4.92	7.14	0.0002	2.62
Within groups	26.2	38	0.69			
Total	45.89	42				

TABLE 7A. Heteroscedastic Two-Tailed T-Test Analysis of
ΔLightness Measurements in Table 5A.
Significant *p*-values noted with asterisk (*)

	***P*-values**			
Sponge Brand	**vs A**	**vs B**	**vs C**	**vs D**
A				
B	0.039*			
C	0.042*	0.002*		
D	0.27	0.0027*	0.11	
E	0.028*	0.0003*	0.54	0.07

4.3 TRIAL 2: NUMBER OF CLEAN SPONGE SURFACES

TABLE 8A. ΔLightness Measurements Comparing Sponge Brand and Number of Clean Sponge Surfaces, with repetitions (*n*=6).

	Number of clean sponge surfaces (Δlightness)			
	1	**2**	**3**	**4**
A	6.37	7.74	10.02	10.16
	6.34	8.54	9.18	9.38
	6.53	8.57	10.35	10.48
	6.30	8.93	9.84	10.48
	6.36	8.34	9.40	9.87
	5.86	7.90	8.72	8.68
mean	6.29	8.34	9.59	9.84
stddev	0.23	0.45	0.60	0.70
B		8.56		10.84
	6.13	9.43	10.44	11.45
	6.42	9.26	10.01	11.53
	5.38	8.61	9.61	10.93
	6.15	8.57	10.16	10.28
	6.22	8.18	9.82	11.01
mean	6.06	8.77	10.01	11.01
stddev	0.40	0.48	0.32	0.45
C	4.49	6.15	6.72	7.48
	5.18	6.63	7.33	7.79
	4.65	6.32	6.46	6.70
	5.33	6.93	7.60	7.85
	5.45	6.11	7.13	7.81
	5.57	7.16	8.01	8.55
mean	5.11	6.55	7.21	7.70
stddev	0.44	0.43	0.57	0.60
D	5.01	7.71	9.40	9.65
	5.90	7.66	8.75	9.90
	5.62	8.05	9.36	10.18
	5.34	7.78	8.36	9.70
	5.32	7.49	8.68	
mean	4.61	6.52	7.52	8.01
stddev	2.06	2.99	3.43	4.14
E	3.76	6.42	7.10	8.09
	4.83	6.59	7.44	8.25
	4.75	6.75	7.92	8.53
	5.17	6.82	7.71	8.19
	5.81	8.19	9.04	10.25
	4.26	6.19	6.75	8.15
mean	4.76	6.83	7.66	8.58
stddev	0.71	0.71	0.80	0.83

4.3 TRIAL 2: NUMBER OF CLEAN SPONGE SURFACES (cont.)

TABLE 9A. Pairwise Comparison Analysis of ΔLightness Measurements from Table 8A, Comparing Sponge Brands for Each Number of Clean Sponge Surfaces. Significant *p*-values noted with asterisk (*)

		Number of clean sponge surfaces			
Sponge Brand		**1**	**2**	**3**	**4**
A	**B**	0.3	0.15	0.19	0.012*
A	**C**	$9.4x10^{-4}$*	$9.7x10^{-5}$*	$9.7x10^{-5}$*	$4.9x10^{-4}$*
A	**D**	0.003*	0.027*	0.075	0.96
A	**E**	0.004*	0.003*	0.0016*	0.023*
B	**C**	0.007*	$2.9x10^{-5}$*	$2.6x10^{-5}$*	$8x10^{-6}$*
B	**D**	0.036*	0.003*	0.0043*	0.002*
B	**E**	0.007*	$7.4x10^{-4}$*	$6.9x10^{-4}$*	$5.8x10^{-4}$*
C	**D**	0.22	$8.6x10^{-4}$*	$7.4x10^{-4}$*	$2.3x10^{-4}$*
C	**E**	0.36	0.46	0.31	0.08
D	**E**	0.08	0.03*	0.02*	0.02*

TABLE 10A: Pairwise Comparison Analysis of ΔLightness Measurements from Table 8A, Comparing Number of Clean Sponges Surfaces within Sponge Brands. Significant *p*-values noted with asterisk (*)

	Number of clean sponge surfaces					
Sponge	**1 vs 2**	**1 vs 3**	**1 vs 4**	**2 vs 3**	**2 vs 4**	**3 vs 4**
A	$4.7x10^{-5}$*	$3.2\ x10^{-5}$*	$6.6\ x10^{-5}$*	0.004*	0.003*	0.53
B	$1.3x10^{-5}$*	$2.3\ x10^{-6}$*	$5x10^{-7}$*	0.001*	$3x10^{-5}$*	0.003*
C	$4.3x10^{-4}$*	$1.1x10^{-4}$*	$4.1x10^{-5}$*	0.06	0.006*	0.2
D	$2.4x10^{-5}$*	$8x10^{-6}$*	$1.4x10^{-6}$*	0.004*	$3x10^{-5}$*	0.009*
E	$9.4x10^{-4}$*	$1.5x10^{-5}$*	$2.9x10^{-5}$*	0.1	0.004*	0.09

4.4.1 TRIAL 3A: DISPLACEMENT OF YARNS

TABLE 11A. Number and Percent of Displaced Yarns Categorized by Percent Change from Untreated Sample, Using Two Clean Sponge Surfaces along 0.5cm Warp and Weft Folds, (*n*=5)

	Number of displaced yarns				Percent of displaced yarns			
Sponge	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**0-25%**	**26-50%**	**51-75%**	**76-100%**
A	33	2	0	0	94%	6%	0%	0%
	35	0	0	0	100%	0%	0%	0%
	35	1	0	0	97%	3%	0%	0%
	33	2	0	0	94%	6%	0%	0%
	30	5	0	0	86%	14%	0%	0%
mean	33.20	2.00	0	0	0.94	0.06	0	0
stdev	1.83	1.67	0	0	0.05	0.05	0	0
B	28	6	1	0	80%	17%	3%	0%
	33	2	0	0	94%	6%	0%	0%
	26	7	1	0	76%	21%	3%	0%
	34	1	0	0	97%	3%	0%	0%
	31	3	0	0	91%	9%	0%	0%
mean	30.40	3.80	0.40	0	0.88	0.11	0.01	0
stdev	3.01	2.32	0.49	0	0.08	0.07	0.01	0
C	33	2	0	0	94%	6%	0%	0%
	33	2	0	0	94%	6%	0%	0%
	31	3	0	0	91%	9%	0%	0%
	34	1	0	0	97%	3%	0%	0%
	38	0	0	0	100%	0%	0%	0%
mean	33.80	1.60	0	0	0.95	0.05	0	0
stdev	2.32	1.02	0	0	0.03	0.03	0	0
D	30	2	0	0	94%	6%	0%	0%
	27	3	0	0	90%	10%	0%	0%
	34	3	0	0	92%	8%	0%	0%
	31	2	0	0	94%	6%	0%	0%
	31	1	0	0	97%	3%	0%	0%
mean	30.60	2.20	0	0	0.93	0.07	0	0
stdev	2.24	0.75	0	0	0.02	0.02	0	0
E	31	4	0	0	89%	11%	0%	0%
	31	2	0	0	94%	6%	0%	0%
	35	0	0	0	100%	0%	0%	0%
	32	2	0	0	94%	6%	0%	0%
	34	1	0	0	97%	3%	0%	0%
mean	32.60	1.80	0.00	0.00	0.95	0.05	0.00	0.00
stdev	1.62	1.33	0.00	0.00	0.04	0.04	0.00	0.00

4.4.1 TRIAL 3A: DISPLACEMENT OF YARNS

TABLE 12A. Number and Percent of Displaced Yarns Categorized by Percent Change from Untreated Sample, Using Four Clean Sponge Surfaces along 0.5cm Warp and Weft Folds, (n=5)

	Number of displaced yarns				Percent of displaced yarns			
Sponge	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**0-25%**	**26-50%**	**51-75%**	**76-100%**
A	32	4	0	0	89%	11%	0%	0%
	29	5	1	0	83%	14%	3%	0%
	34	1	0	0	97%	3%	0%	0%
	31	3	0	0	91%	9%	0%	0%
	31	4	0	0	89%	11%	0%	0%
mean	31.40	3.40	0.20	0	0.90	0.10	0.01	0%
stdev	1.62	1.36	0.40	0	0.05	0.04	0.01	0%
B	28	7	0	0	80%	20%	0%	0%
	34	2	0	0	94%	6%	0%	0%
	27	8	0	0	77%	23%	0%	0%
	35	1	0	0	97%	3%	0%	0%
	32	1	3	0	89%	3%	8%	0%
mean	31.20	3.80	0.60	0	0.88	0.11	0.02	0%
stdev	3.19	3.06	1.20	0	0.08	0.09	0.03	0%
C	30	3	0	0	91%	9%	0%	0%
	28	5	1	0	82%	15%	3%	0%
	31	2	1	0	91%	6%	3%	0%
	31	3	1	0	89%	9%	3%	0%
	37	3	0	0	93%	8%	0%	0%
mean	31.40	3.20	0.60	0	0.89	0.09	0.02	0%
stdev	3.01	0.98	0.49	0	0.04	0.03	0.01	0%
D	28	4	0	0	88%	13%	0%	0%
	25	3	1	0	86%	10%	3%	0%
	36	1	0	0	97%	3%	0%	0%
	29	4	0	0	88%	12%	0%	0%
	29	1	0	0	97%	3%	0%	0%
mean	29.40	2.60	0.20	0	0.91	0.08	0.01	0%
stdev	3.61	1.36	0.40	0	0.05	0.04	0.01	0%
E	33	2	0	0	94%	6%	0%	0%
	31	3	0	0	91%	9%	0%	0%
	33	1	0	0	97%	3%	0%	0%
	33	2	0	0	94%	6%	0%	0%
	35	1	0	0	97%	3%	0%	0%
mean	33.00	1.80	0	0	0.95	0.05	0%	0%
stdev	1.26	0.75	0	0	0.02	0.02	0%	0%

4.4.2 TRIAL 3B: DISPLACEMENT OF FIBER ENDS

TABLE 13A. Number of Loose Fiber Ends along 0.5cm Fold, Comparing Sponge Brands and Number of Clean Sponge Surfaces, (n=3)

	Number of clean sponge sponges (loose fiber ends)		
Sponge	**0**	**2**	**4**
	23	20	20
A	16	11	13
	19	17	15
	10	12	9
B	23	18	11
	19	14	17
	19	12	15
C	27	20	16
	24	9	17
	17	16	15
D	32	21	24
	18	18	9
	22	18	15
E	21	19	18
	27	20	12
mean	21.13	16.33	15.067
stddev	5.3	3.81	4.0083

TABLE 14A. Two Factor ANOVA Analysis Comparing Sponge Brands and Number of Clean Sponge Surface with Number of Fiber Ends from Table 13A.

Source of Variation	**SS**	**df**	**MS**	**F**	***P*-value**	**F crit**
Sponge brands	109.02	4.00	27.26	1.27	0.30	2.69
Number of clean sponge surfaces	307.24	2.00	153.62	7.18	0.003	3.32
Interaction	70.98	8.00	8.87	0.41	0.90	2.27
Within	642.00	30.00	21.40			
Total	1129.24	44.00				

4.4.2 TRIAL 3B: DISPLACEMENT OF FIBER ENDS (cont.)

TABLE 15A. Two-Tailed T-Test Comparison of Number of Clean Sponge Surfaces for All Tested Brands. Significant *p*-values noted with asterisk (*)

	Number of Clean Sponge Surfaces		
	0 vs 2	**2 vs 4**	**0 vs 4**
***P*-value**	0.0086*	0.38	0.0015*

4.5 RESIDE

TABLE 16A. Size and Quantity of Debris after 20 Tamps viewed at 40X, *n*=3. For each repetition three areas were counted and measured.

Sponge	Repetition	Slide location	Smallest debris (um sq)	Largest debris (um sq)	number of debris
		a	< 1	40	800
		b	< 1	95	600
	1	c	< 1	455	600
		a	< 1	118	500
		b	< 1	67	400
	2	c	< 1	540	800
		a	< 1	122	500
		b	< 1	875	600
A	3	c	< 1	80	800
		a	< 1	90	21
		b	< 1	8	7
	1	c	< 1	10	14
		a	< 1	80	7
		b	< 1	11	15
	2	c	< 1	6	138
		a	< 1	47	11
		b	< 1	104	19
B	3	c	< 1	38	8
		a	<1	278	500
		b	<1	180	600
	1	c	<1	60	400
		a	<1	488	700
		b	<1	260	400
	2	c	<1	680	500
		a	<1	219	600
		b	<1	208	400
C	3	c	<1	780	600
		a	<1	26	54
		b	<1	140	67
	1	c	<1	180	63
		a	<1	69	45
		b	<1	70	46
	2	c	<1	84	58
		a	<1	250	102
		b	<1	82	100
D	3	c	<1	48	99
		a	<1	38	80
		b	<1-5	66	250
	1	c	<1-5	44	200
		a	2	4	3
		b	1	520	6
	2	c	1	360	28
		a	<1	10	27
		b	1	20	25
E	3	c	<1	7	5

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